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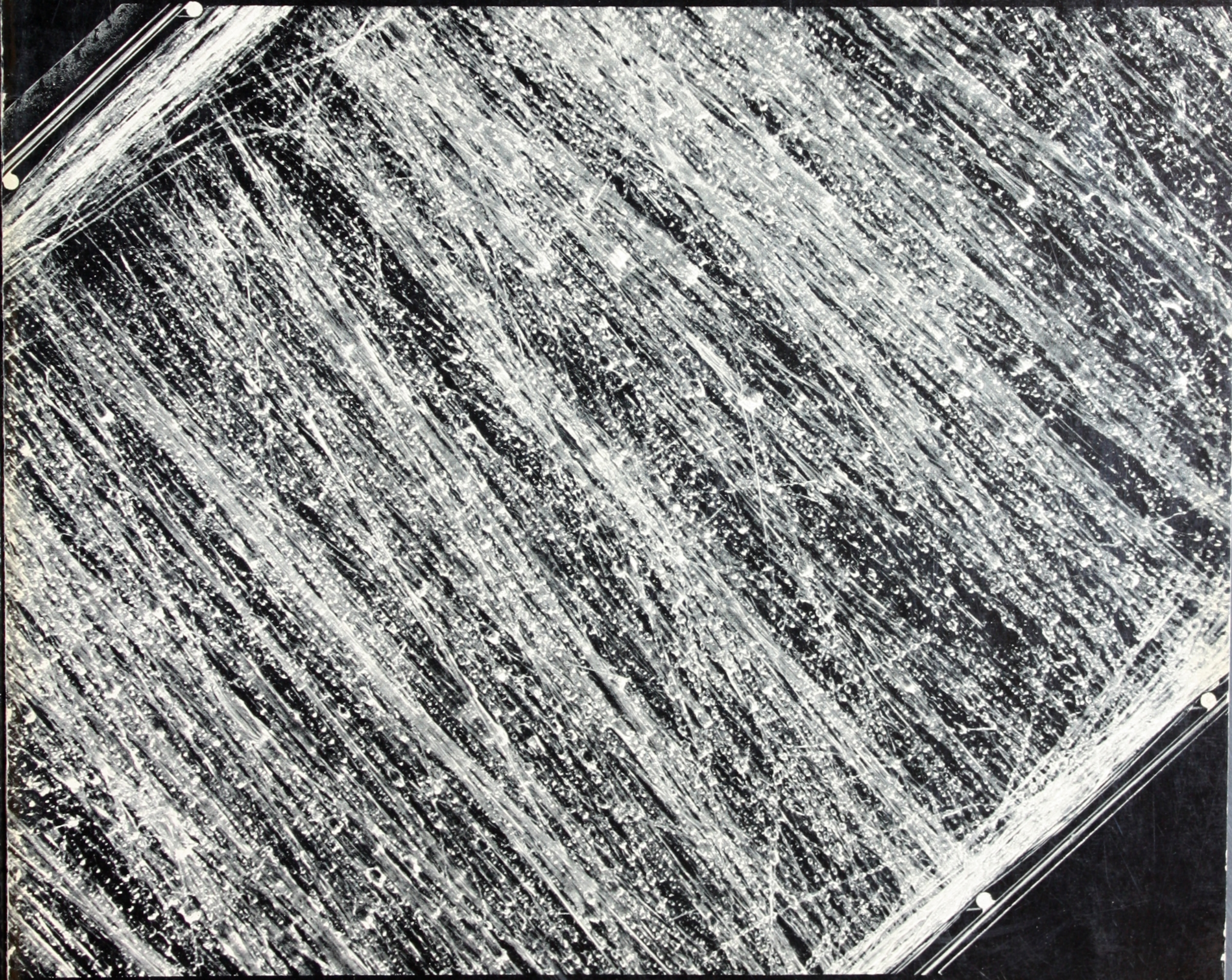
A.I.A. FILE 30F.

CAPILLARY AIR CONDITIONERS



AIR & REFRIGERATION CORPORATION

475 FIFTH AVENUE, NEW YORK CITY

ATLANTA, GEORGIA DETROIT, MICHIGAN

A.I.A. FILE 30F.

CAPILLARY AIR CONDITIONERS

air Conditioning

INTRODUCTION

THE efficiency of a system designed for the heating, cooling, humidifying, dehumidifying or cleansing of air depends upon the degree of *contact* established between the air and the heating, cooling or cleaning medium.

Heaters and coolers passed through the developments involving sundry shapes of cast iron and pipe coil surfaces to produce the greatest possible *contact* and from this, turned to the various forms of light weight, finned copper tubes now commonly used for heating and cooling.

The development of humidifiers and air washers involved various mechanical means for breaking up or atomizing water to offer *contact* with the air. From such atomizing systems, the atomizing or spray type dehumidifier and cooler was also developed, wherein the apparent paradox of reducing humidity by passing air through a water or brine spray was accomplished.

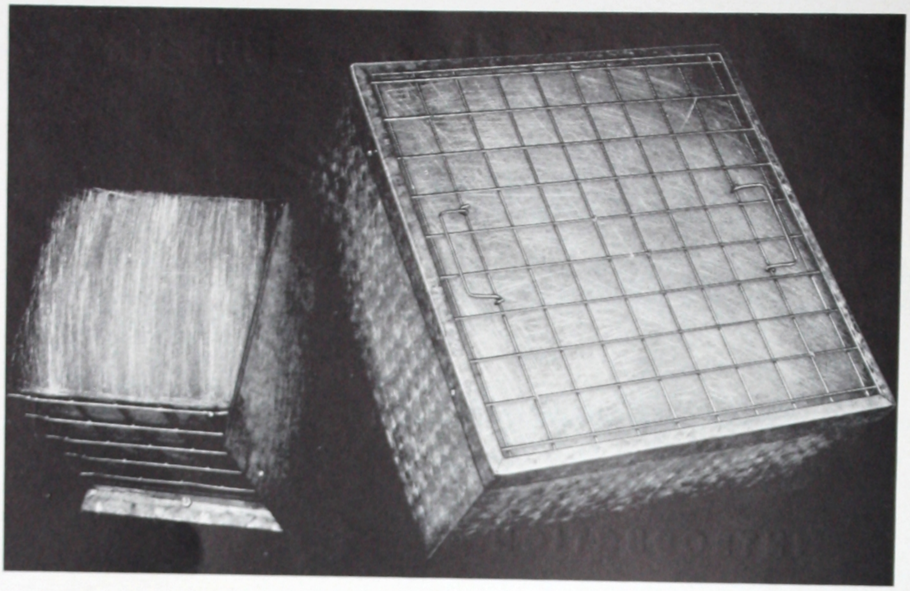
Finally, air filters depend for their efficiency upon the intimacy of *contact* between the air and the dust retaining surfaces.

The Capillary air conditioner, designed to act as an air washer, dust arrester, humidifier, cooler and dehumidifier, depends like all of the equipment cited above, upon the efficiency of *contact* for effective action. Beyond this, however, there is little similarity between Capillary conditioners and other heat exchange and cleaning equipment. The development of the Capillary principle marked an entirely new advance in air conditioning. It departed from the practice of large quantities of water finely atomized at considerable expense in pumping equipment and power and offered a means whereby the most intimate and efficient contact between air and the cooling, moistening or cleaning fluid could be achieved at small cost in power and equipment. In place of atomizing the fluid in a moving mass of air, more efficient contact was achieved by dividing *both* the water and air into fine streams flowing together through low resistance channels. The method employed was so revolutionary that basic patents were granted and others are pending. Air and Refrigeration Corporation, as well as other prominent manufacturers of fan and air conditioning equipment, are licensed to manufacture Capillary Conditioners under these U. S. Patents Nos. 2054809, 2132457, 2139675, and 2149593.

Since 1935, when Capillary conditioners were first introduced, many successful installations have been made in comfort and industrial applications. Many of these have been outstanding and have included such installations as: the Industrial Rayon Corp. plant at Painesville, Ohio, wherein approximately 1,500,000 cu. ft. of air per minute are passed through Capillary Conditioners. The American Smelting and Refining Company, at Corpus Christi, Texas, cools 160,000 cfm through Capillaries to maintain D.C. generators at efficient operating temperatures. Pratt & Whitney Aircraft at East Hartford, Conn., bring in 120,000 cfm through Capillaries to a single metal annodizing and painting department to replace with clean positively supplied air, the air exhausted over numerous tanks and ovens.

Tubize Chatillon Corporation, manufacturers of Rayon at Rome, Georgia, have Capillary units in which the cells have been in continuous use for five years without replacement. DuPont, Goodyear, Fisher Body, Allison Engine, Wright Aeronautical are other nationally known names to be found among the users of Capillary Conditioners.

CAPILLARY
TRADE MARK REG. U.S. PAT OFFICE



At left a standard Capillary cell is shown, complete with casing and screens. The cut-away section shows clearly the oriented glass filaments and the thin horizontal layers at the entering and leaving faces.

The front cover of this book is a photograph in full scale of a section of Capillary cell. It shows accurately and distinctly the arrangement of the glass filaments and the actual progress of water through the cell.

THE CAPILLARY CELL

The basic element of the Capillary conditioner is the Capillary cell. Each cell consists of a standard casing 20″ x 20″ in face dimensions and 8″ in depth. The photograph which forms the cover of this book, as well as other included illustrations, will aid in understanding the structure of the cell. The entire cell casing is filled with fine glass filaments. Through the 8 inch depth of the cell these filaments are arranged essentially parallel to the direction of air flow through the cell. At the entering and leaving face, a thin layer of filaments is arranged at right angles to the parallel or oriented strands running through the cell.

A 2″ galvanized mesh screen is fixed to each face as part of the supporting structure for the filaments and to reduce the chance of damage to the glass. Further support is provided for the oriented strands by a patented system of lacings consisting of permanent glass twine running through the cell.

In operation, water is sprayed at low pressure over the thin, horizontal layer of glass at the face of the cell. This thin layer serves the important function of spreading the liquid uniformly over the face area. The water then flows along the thousands of oriented strands through the depth of the cell, either concurrent with or counter to the direction of the air streams. At the leaving face of the cell, the liquid is again collected on the thin horizontal layer of filaments where it clings by capillary action until large drops are formed. This characteristic prevents the carry over or entrainment of free moisture in the air stream and allows the use of simple, low resistant eliminators.

There are approximately 57,000 separate strands of glass in a single cell. The gross area of this glass surface is about 125 square feet. Regardless of the quantity of water flowed upon the surface and leaving a cell, the residual water distributed upon the strands within a cell at any moment is approximately 6 pounds or .096 cubic feet. This volume of water spread over the 125 square feet of internal surface would establish a film averaging less than 1/100th of an inch in thickness. This, when considered with the fact that the air stream passing through the cell is divided into thousands of small streams in *contact* with the wetted strands, accounts for the wholly new order of efficiency in saturation, heat exchange, cleaning and absorption established by the Capillary cell.

Rated Capacity of Capillary Cells

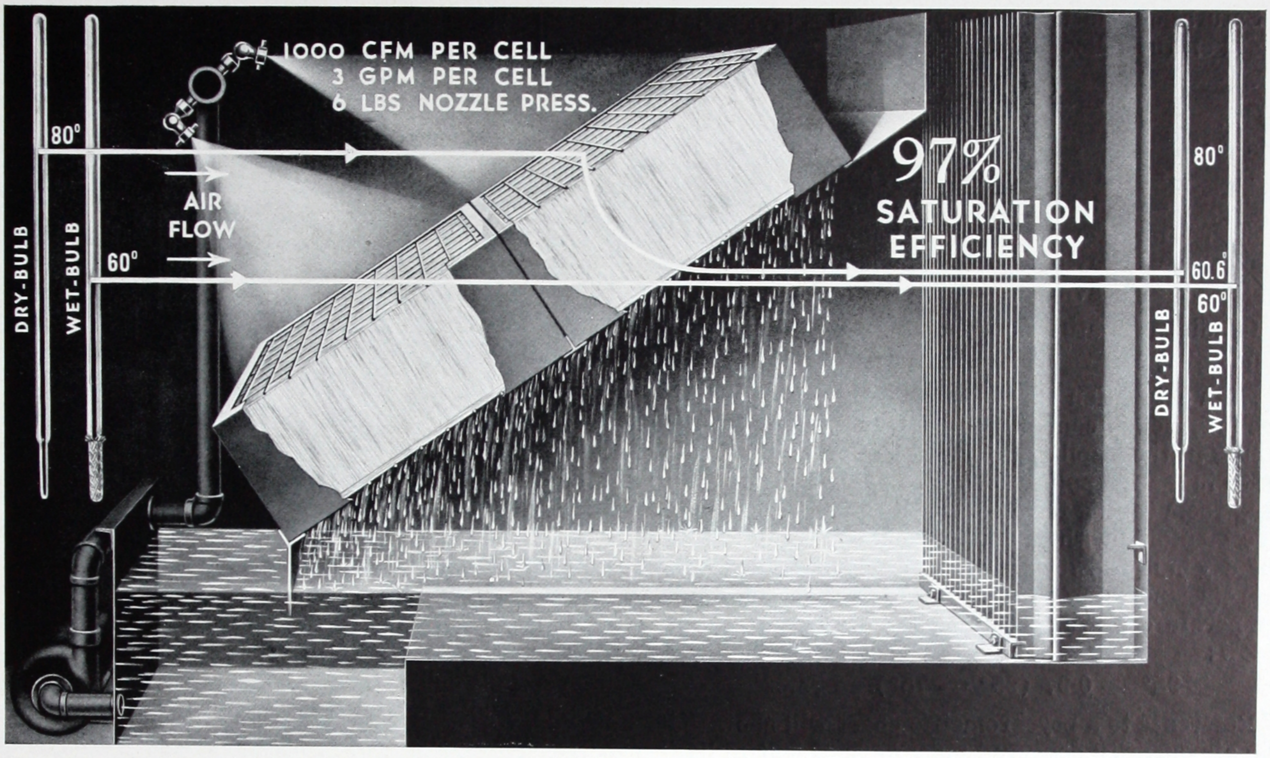
The maximum air volume recommended for each 20″ x 20″ cell is 1100 cfm. Nominal ratings for cell assemblies in various combinations is 1000 cfm per cell.

The water quantity used for simple air washing, humidifying and evaporative cooling is 3 gpm per cell or per 1000 cfm. For cooling and dehumidifying the water quantity will, of course, depend upon the initial air wet bulb temperature, the initial temperature of available water and the desired final air temperature. The maximum water quantity recommended per cell is 9 gpm.

See *Engineering and Performance Data,* page 18.

Resistance to Air Flow

Although the filaments appear to fill the cell completely, they actually occupy about one and one-half per cent of the cell volume. This fact, combined with the parallel arrangement of the filaments, accounts for the exceptionally low resistance to air flow as shown for various air and water quantities in the tables on page 19.



This illustration demonstrates graphically how air is cooled adiabatically in passing through a Capillary conditioner. Dehumidifying as well as cooling may be accomplished by applying chilled water to the cells.

FUNCTIONS OF THE CAPILLARY CELL

Humidifying and Saturation Efficiency

Capillary conditioners are ideally adapted to systems calling for the humidification as well as cleaning of large quantities of outside air, as in textile mills, ammunition plants, biological laboratories, hospital operating theatres and many other industrial applications.

The most positive and satisfactory control of relative humidity within a conditioned space is accomplished by fixing the dew-point temperature; i.e. the *absolute humidity* at the conditioning unit. The *relative humidity* within the space is then set by controlling the degree of temperature rise above the dew point temperature. This is done either by varying the quantity of saturated air delivered to the space or by automatically controlled reheating of the air after saturation in the humidifier.

When using recirculated water over the Capillary cells, the air leaves the cells virtually saturated at the entering wet bulb temperature. In other words, the process of saturating the body of air passing through a Capillary cell is exactly the same as that which takes place in saturating a *film* of air passing around the wick of a wet bulb thermometer.

High saturation efficiency is emphasized as an important feature of the Capillary cell and is indicated by the capacity to reduce the temperature of the air to a point essentially the same as the entering wet-bulb temperature. Figure 1, page 3, shows the saturation efficiency of the standard cell at varying air velocities with water flowing through the cell at a constant rate of 3 gpm. It will be observed from this curve that saturation efficiency varies less than 3 per cent over a velocity variation of 230 per cent. This performance is unique in the Capillary conditioner.

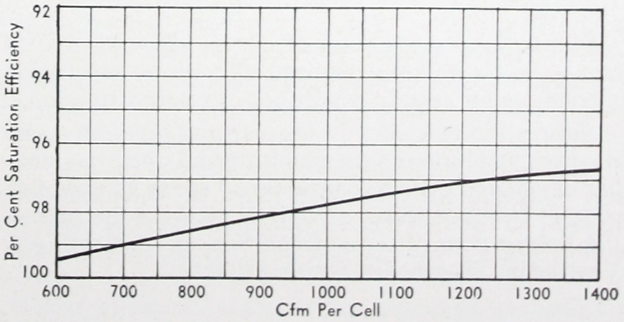


FIG. 1. Saturating Efficiency at Various Air Volumes.

Saturation efficiency, as shown in Figure 1, is based on the following formula:

$$E = \frac{(t - t_1) - (t_2 - t_3)}{(t - t_1)} \times 100$$

where:

E = Saturation efficiency, per cent.
t = Entering dry bulb temperature
t_1 = Entering wet bulb temperature
t_2 = Leaving dry bulb temperature
t_3 = Leaving wet bulb temperature

In adiabatic saturation, t_1 and t_3 are essentially the same.

High saturation efficiency is another indication of the intimacy of contact between air and liquid which occurs in the Capillary cell and has practical importance in many applications. For example: in a spinning room calling for a condition of 70 per cent relative humidity with prevailing outdoor conditions at 95° dry bulb and 75° wet bulb temperature, a saturation efficiency of 97 per cent would produce a dry bulb temperature of 75.6° leaving the washer as shown below:

$$95^\circ - 0.97\ (95^\circ - 75^\circ) = 75.6^\circ$$

Reference to a psychrometric chart will show that the air quantity delivered must be sufficient to limit the rise in the room to 85.7° in order to maintain the 70 per cent relative humidity required.

For each 1000 BTU's per minute to be absorbed in the room, the air quantity would be:

$$Q = \frac{1000 \times 56^*}{85.7^\circ - 75.6^\circ} = 5550 \text{ cfm}$$

A washer having a saturation efficiency of 90 per cent would deliver air at a dry bulb temperature of 77°, the required room temperature would be 85.2° and air quantity would be:

$$Q = \frac{1000 \times 56}{85.2^\circ - 77^\circ} = 6830 \text{ cfm}$$

Thus a decrease of 7 per cent in saturation efficiency, at the conditions outlined, increases the required air quantity by 23 per cent, necessitating larger apparatus and distributing ducts, increasing initial costs and the costs of operation in fan and pumping power.

Figure 2 presents a set of curves showing the increase in air volume required at various saturation efficiencies for several conditions of relative humidity.

Saturation efficiency in the various types of spray washers and humidifiers which depend upon the number of nozzles and the character of spray to establish contact between water and air is given in the following listing from the American Society of Heating & Ventilating Engineers' Guide (1942):

$$^*\ \frac{\text{Air density 13.5 cu. ft. per lb.}}{\text{Specific heat of air 0.241}} = 56$$

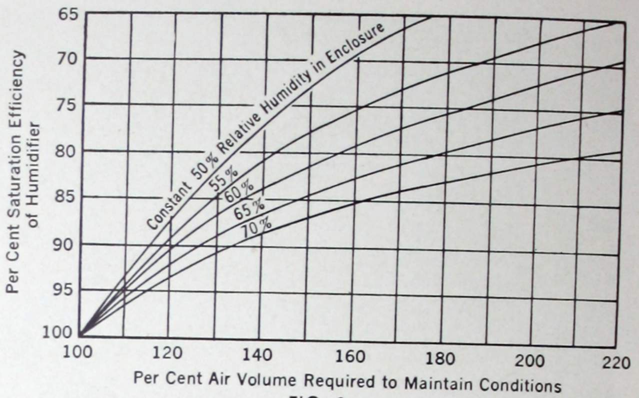


FIG. 2

	Saturation Efficiency
1 Bank of sprays Downstream	60 to 70 per cent
1 Bank of sprays Upstream	65 to 75 " "
2 Banks of sprays Downstream	85 to 90 " "
2 Banks of sprays—1 Downstream and 1 Upstream	90 to 95 " "

To achieve the above efficiencies requires, in the order presented, from 5½ gallons of water per minute per 1000 cubic feet of air for a single bank downstream washer to 15 gpm per 1000 cfm for the most efficient two bank units. The required nozzle pressures range from 15 to 20 lbs with overall recirculating pump heads ranging from 45 to 70 feet.

The Capillary cell offers 97 per cent saturation efficiency with 3 gpm per 1000 cfm. The required nozzle pressure is 6 lbs and the overall pumping head of all units is approximately 22½ feet plus the height in feet between the tank and the top spray header.

The saving in pumping in power and the reduced size and initial cost of pumping equipment, made possible through the efficiency of the Capillary cell is evident in the above comparison.

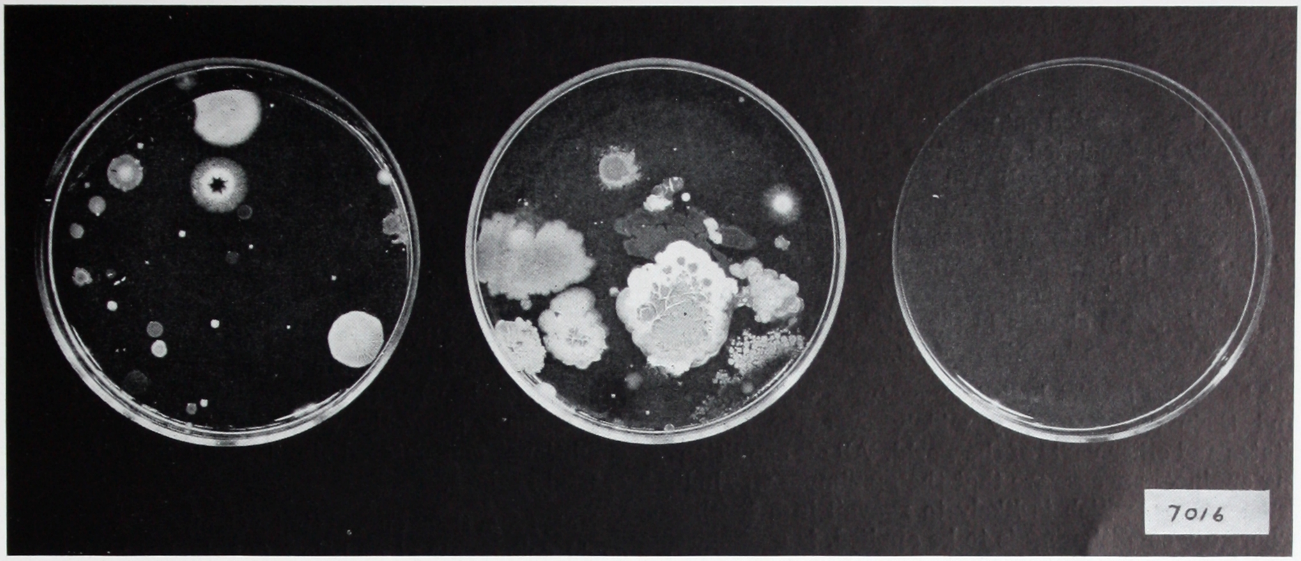
As a matter of fact, the same saturation efficiency in the Capillary cell may be obtained with as little as 0.6 gpm; 3 gpm was set as the standard minimum in order to assure effective and continuous flushing of the cells.

Air Cleaning and Air Washing

A primary requirement of nearly all air conditioning or simple ventilation systems is to remove from the out-door air or from recirculated air as much of the air-borne solid matter as is physically or economically practicable.

It is common in many types of air conditioning equipment to call for air filters in advance of humidifiers, heaters, cooling coils and even in advance of air washers.

The dust and spore removal performance of the Capillary cell ranks with the best dry and viscous type filters. In practice, the cells remove in excess of



Photograph showing results of mold and spore elimination test after seventy-two-hour incubation period.

95 per cent by weight of the air-borne solid matter which includes virtually all particles exceeding 5 microns in size and most of those down to 1 micron.

Since bacteria and mold spores normally adhere to the larger solid particles, the laboratory photograph above will serve to illustrate the efficiency of removal in the Capillary cell of living organisms accompanied by the dust particles. Three petri dishes are shown. Each was coated with a sterile solution of agar-agar. From left to right the plates were exposed; the first, at the entry to a duct leading to the Capillary conditioner; the second, immediately at the entry to the conditioner and the last, immediately after the conditioner. All were exposed for the same period and all were incubated at constant temperature and humidity for 72 hours after exposure.

The Capillary Cell Is Self-Cleaning

The constant flushing of water through the cell carries the dirt through the cell to a settling tank, where it is collected by a strainer or ultimately flushed to the sewer. Under normal conditions, the self-cleaning action of Capillary cells allows long periods of operation with no measurable increase in resistance to air flow and no call for cleaning or replacement. Where some of the dirt arrested by the cell may be of a character to coagulate upon the filaments, such as some forms of grease or other sticky substances, periodic cleaning procedures have been developed, which are applied to meet the specific requirements.

For installations where air carries large pieces of flying lint, as in cotton mills, or hair or fur, as in hat factories, a simple preliminary screen or filter is used before the Capillary. This is periodically cleaned or replaced as circumstances indicate.

Absorption of Odorous Gases or Vapors a Part of Cleaning

Many of the objectionable gases and vapors which contaminate the atmosphere in cities and in occupied, enclosed spaces are soluble in contact with water or are caused to condense in contact with cool surfaces. The familiar types of dry or viscous filters have no property to absorb or condense such elements. Even the electrostatic types of dust arresters have no effect upon these gaseous substances.

In the process of cooling and dehumidfying air by means of finned coils through which a cooling fluid is circulated, dry or viscous coated filters may satisfactorily prevent the deposit of solid matter on such coils but vapors, such as described, pass through the filters and condense on the cooling coils. Unless the coils are washed continuously by an effective spray system, these condensable substances, such as greases from food, essential oils from perspiration and tobacco smoke, accumulate on the coils and are a persistent source of malodors in the conditioned air stream.

Capillary cells in advance of coils prevent this accumulation and improve the quality of the air delivered. Capillary cells supplied with chilled water, as later described in detail, act simultaneously to clean and cool and dehumidify the air stream, replacing both filters and coils.

Certain odorless chemicals are available for the treatment of the water applied to the Capillary cells which, in special instances, may be used to improve the absorptive qualities and act to sterilize the air stream and aid in removing objectionable gases. The highly efficient contact surface presented by the Capillary, increases the effectiveness of such solutions.

EVAPORATIVE COOLING

It has been pointed out previously that when water is simply recirculated over the Capillary cell, air passing through the cell will be cooled virtually to its entering wet bulb temperature. This is the simple process of adiabatic saturation in which a portion of the sensible heat of the air, as indicated by the dry bulb thermometer, is converted to latent heat of evaporation. No change in the total heat per pound of air takes place in this process.

The range of wet bulb temperatures which occur and their duration vary widely over the United States and other parts of the world. All air conditioning engineers are aware that the maximum wet bulb temperature, which is likely to prevail in a locality where air conditioning is to be applied, is an important factor governing the design of the system and is known as the *design wet bulb*.

We have long had access to Weather Bureau data to determine the maximum conditions governing design. Up to recent years, however, the Weather Bureau statistics dealt primarily with maximum, minimum, and average conditions primarily for the benefit of agriculture. Available records did not present data on duration of conditions or time of occurrence. With the advent and rapid growth of commercial aviation, the Aerological Division of the United States Weather Bureau began to observe and record almost continuous records of wet and dry bulb temperatures as well as much other atmospheric data in many parts of the continent. This data has now been compiled and published in forms very useful to the air conditioning engineer.*

Figure 3, taken from the A. S. H. & V. E. transactions, shows a map of the United States on which lines are imposed tracing the territories in which the indicated wet bulb temperatures will not be exceeded during more than 5 per cent of the time from June to September, inclusive, during a normal season.

In general these wet bulb temperatures may be used safely for air conditioning capacity design.

For most applications, whenever the outdoor wet bulb temperature is 60 degrees or below, effective cooling and indoor comfort can be maintained by a Capillary unit without refrigeration. In many localities where wet bulb temperatures rarely or never exceed 60 degrees, evaporative cooling suffices at all times without refrigeration or other sources of cooling. In contrast, air conditioning units using only coils for refrigerant or cold water will, in most applications, call for refrigeration whenever the outdoor *dry bulb* temperature exceeds 60 degrees.

Figures 4 and 5 are curves showing the number of hours through a complete year during which given dry bulb and wet bulb temperatures will prevail or be exceeded respectively in Denver, Colo., and Hartford, Conn. These curves have been plotted from United States Weather Bureau observations made at these cities. They show the wide difference in wet bulb conditions encountered in typical mountain and coastal regions.

Note from these curves that a Capillary conditioner could deliver air at or below 60° during all but 800 hours in a season at Denver and 2200 hours at Hartford. On the other hand, a coil system, without available evaporative cooling, would call for refrigeration to deliver 60° air during 2750 hours in a season at Denver and 3000 hours at Hartford.

In most air conditioning applications for human comfort the design conditions call for capacity to maintain 80° dry bulb and 50 per cent relative humidity when outdoor dry and wet bulb temperatures are at the expected maximum for the given territory. The above temperature and humidity would call for a dew-point temperature of 59.7° in the conditioned space. The dew-point temperature of the air supplied to the space, usually termed the apparatus dew-point, must be sufficiently below the above condition to absorb the moisture from people and other sources. For most applications, where there is no unusual internal latent heat load, this would be about 58°.

Since the simple recirculation of water over the Capillary cells will reduce air approximately to the prevailing outdoor wet bulb temperature, it is obvious that no refrigeration or other external source of cooling would be required to maintain the above conditions whenever the outdoor wet bulb temperature is at 58° or below.

The shaded areas between the 58° line and the wet bulb line present a direct comparison between the required refrigeration load in the two territories. Note that refrigeration would be required at Hartford during 2350 hours, contrasted with 1250 hours at Denver.

Reasonably accurate estimates of refrigeration requirements in terms of *ton-hours per year* and from this, estimates of power consumption and seasonal costs may be made from a study of such areas applied on the degree-hour curves.

* Analysis of Summer Weather Data, by J. C. Albright, and Application of Summer Weather Data, by John Everetts, Jr. Trans. Am. Soc. Heat. & Vent. Engrs., pp. 397-431, Vol. 45, 1939.

* Summer Weather Data with Design Data, Statistics, Charts, Maps and Technical Analysis. Compiled and Edited by J. C. Albright. Published by The Marley Company, Kansas City, Kansas. Price, $3.00.

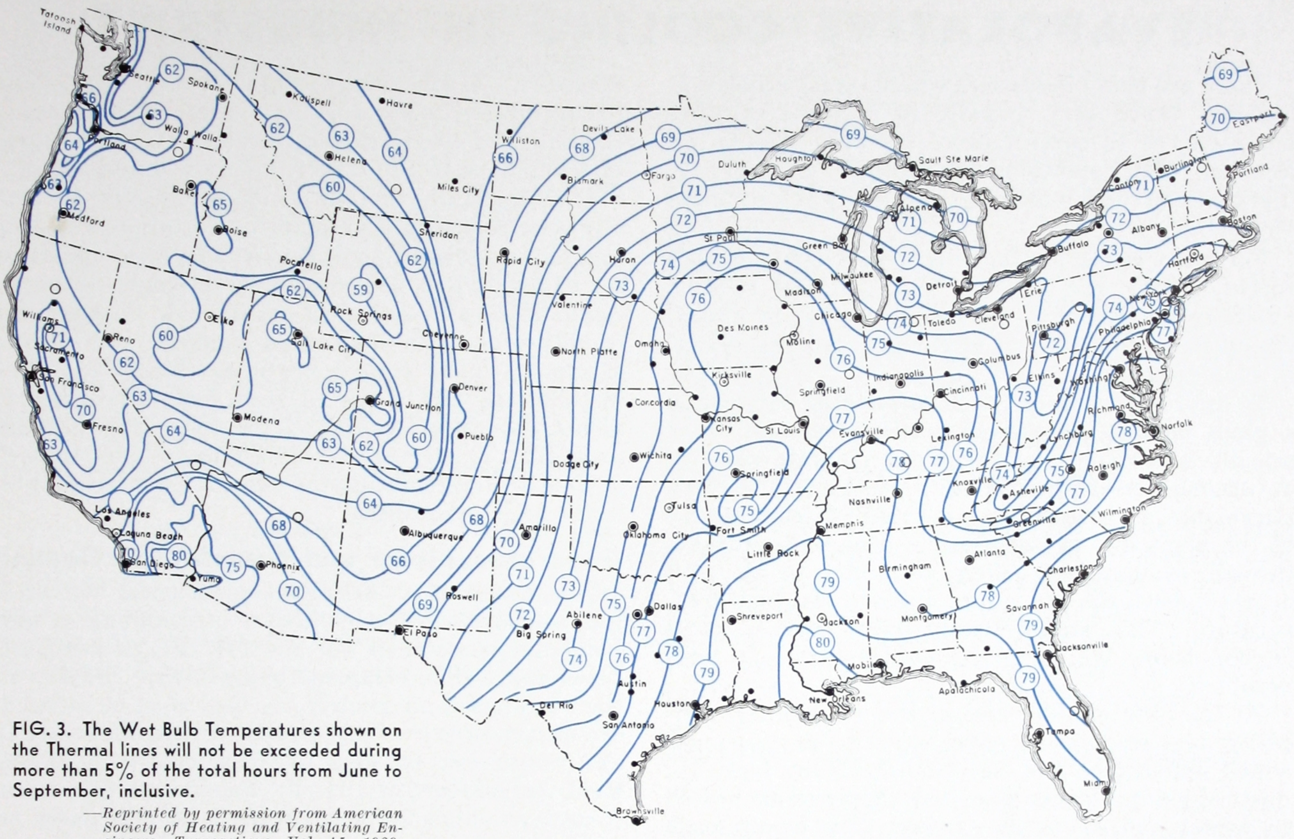
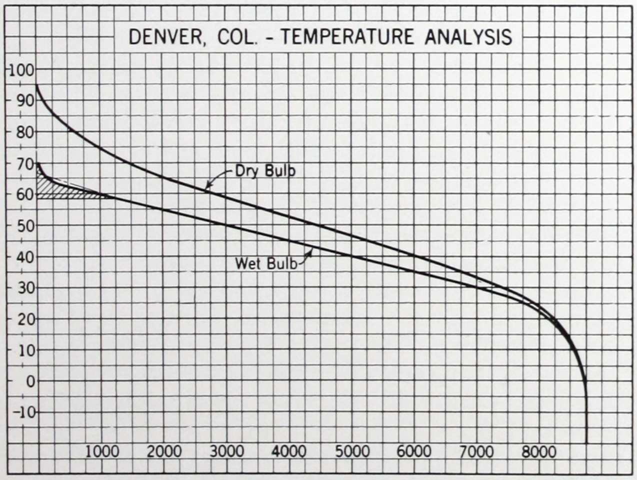
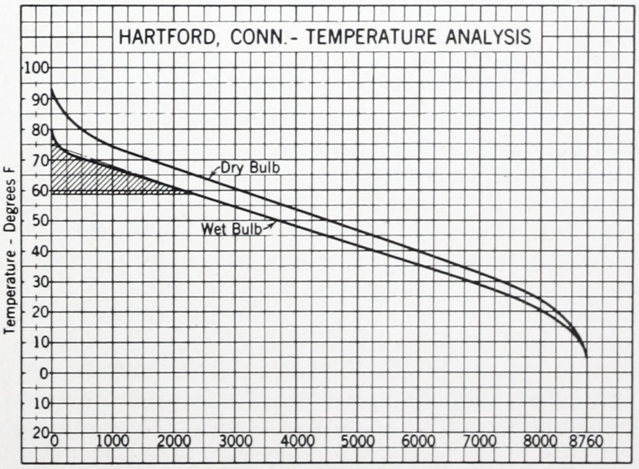


FIG. 3. The Wet Bulb Temperatures shown on the Thermal lines will not be exceeded during more than 5% of the total hours from June to September, inclusive.

—*Reprinted by permission from American Society of Heating and Ventilating Engineers—Transactions, Vol. 45, 1939.*





Air and Refrigeration Corporation has made analyses of loads and operating costs for numerous localities and will be pleased to cooperate with engineers by applying these studies to specific problems which they may have. In almost all cases the application of Capillary Conditioners will show a substantial saving in annual operating costs, as well as the many other advantages in the quality of conditioning which are touched upon in this book.

EVAPORATIVE COOLING IN INDUSTRIES

There are many industries where evaporative cooling may serve very usefully to improve working conditions or to control processes even though, on occasion, the conditions established may depart slightly from those which we consider ideal for human comfort.

For many years, textile mills have relied on evaporative cooling not only to maintain the relative humidity necessary to the processes, but to absorb the enormous amounts of mechanical heat generated in such mills.

To approach outdoor conditions during summer in a plant having considerable mechanical and other sensible heat loads, would require an infinite quantity of unconditioned outdoor air; whereas, with very reasonable air quantities, the rise of temperature in the plant due to the sensible heat released may, through evaporative cooling, be limited to 12 or 15 degrees above the prevailing outdoor wet bulb temperature. This would usually mean from 5 to 10 degrees below the prevailing outdoor dry bulb temperature.

At the date of this catalog, the availability, simplicity and economy of evaporative cooling assumes added importance and significance. Many large industrial plants require a positive supply of air heated in winter and cooled in summer. The heavy loads involved may bar refrigeration economically even in normal times. In the present national emergency, not only copper and other materials, required in refrigeration equipment are not readily available, but the element of time is important. Many factories may be "blacked out" and a source of heat absorbing air is essential to maintain livable conditions.

The most simple solution is to provide evaporative cooling which will reduce, by at least 50 per cent, the air quantity required to maintain bearable conditions at all times and through the greater part of the year will allow ideal conditions to be maintained.

In the future, when refrigeration equipment is more readily available and if the addition of such equipment is economically justified, it can always be added. Capillary conditioners simply require a source of cold water for distribution over the cells to cool and dehumidify air to a desired saturation or dew-point temperature.

Spot Cooling and Make-up Air

Many industries have processes which create localized hot areas in which exceedingly difficult working conditions prevail. Such is the case in heat treating and annealing departments, at the leaving end of continuous paint bake ovens, around enamel furnaces and the like. In such instances, evaporative cooling provides adequate relief and contributes to efficiency. A well designed system would distribute the air directly to the working zone and would place in the hands of the workmen, themselves, some degree of manual control to direct the air where desired.

It happens also that such industrial processes usually require substantial quantities of air to make up for the large quantities exhausted. In spray painting, for example, it is necessary that the make-up air be clean. Here, as in many other instances, Capillary air conditioners, with their high cleaning and cooling efficiency, fulfill a dual purpose. Many Capillary installations are in use to meet just these requirements, providing a controlled positive supply of clean make-up air, barring the infiltration of dirt ladened outside air, eliminiating the expense of filter maintenance and replacement.

Generator, Motor and Transformer Cooling

The rating of electrical generators and motors is generally based on a maximum surrounding or ambient temperature of 40° C.; 104° F. At temperatures above this, excessive temperatures develop in the windings or alternately, the load must be reduced. The permissible overload on the average alternator is about 6 per cent for each 10° F. below the rated ambient temperature of 104° F. This means that if air is made available to the windings at 75°, the motor or generator may be operated at approximately 16 per cent overload without exceeding the normal temperature rise in the windings.

Capillary conditioners applied for this purpose deliver air essentially at the prevailing outdoor wet bulb temperature which, as previously stated, rarely exceeds 75° in most localities. By the use of evaporative cooling through Capillary conditioners, generators and large mill motors, new and old, operating in confined or hot spaces, may be brought up to their normal rating or even safely overloaded within the limits recommended by the manufacturers, usually not to exceed 15 per cent.

In the case of transformers, the amount of overload at reduced ambient temperatures are covered by A. S. A. standards. These give 1 per cent increase over the rating for each degree centigrade by which the ambient is below 30° C., while the possible loading is reduced 2 per cent for each degree above 30° C. The manufacturer's permissible overload on transformers is limited to 30 per cent, even at less than 0° C. ambient.

A further protection lies in the cleaning of the air passing through the Capillary, this prevents dust and lint accumulation in windings which may prove a fire hazard and gradually obstructs circulation through the windings. Furthermore, the useful life of electrical insulation is approximately halved for each 10° C. increase in operating temperature.

COOLING AND DEHUMIDIFYING WITH CAPILLARY CONDITIONERS

To accomplish cooling and dehumidification of air passing through Capillary conditioners simply requires a supply of cold water from wells, from an ice melting bunker or mechanically chilled water. The quantity of water required, of course, depends upon the initial air and water temperatures and the required final dew-point or saturation temperature of the air.

The structure of Capillary cells and the efficient contact established between gas and fluid is in this case again responsible for heat transfer rates not obtainable with the usual spray type dehumidifiers.

There is considerable flexibility in the arrangement of cells to achieve desired cooling results. The schematic diagrams on pages 12 and 13 outline the various arrangements. A study of these diagrams and the use of the performance charts will readily indicate the proper selection for any specific application.

In considering Capillary units for an air conditioning application which calls for cooling and dehumidifying during a portion of the year, it is well to remember:

(1) That a Capillary conditioner saves many hours of refrigeration through evaporative cooling, whenever the outdoor wet bulb temperature is at or below the required dew-point.

(2) That filters are not required with Capillary conditioners.

(3) That air washing in the Capillary cells absorbs, condenses and carries away many substances which would normally be condensed on coils, only to contribute disagreeable odors to the conditioned air stream.

(4) Capillary cells provide means for year-round, accurate humidity control.

(5) If refrigeration breaks down or for other reasons is not available, evaporative cooling through Capillary cells is always available, whereas uncooled air passing through inactive coils at the outside dry bulb temperature would, in many cases, prove inadequate to absorb internal heat loads and maintain bearable conditions.

OTHER USES FOR CAPILLARY CELLS

The intimate contact of gas with fluid, which is characteristic of Capillary cells, suggests many useful applications other than for air conditioning. The following list of possible applications is presented for the consideration of engineers and manufacturers. The applications suggested will usually require special *study* to determine the best means to meet the particular requirements. Glass, which forms the body of the cells, is unaffected by most gases and liquids. Where corrosive substances are to be handled, special materials may be used for the cell casing and screens. For example, a fully rubber-coated cell casing is now available.

Absorption of Fumes and Gases

Many industrial processes involve the discharge of fumes to the outer atmosphere. Frequently such disposal presents a nuisance problem or may be actually damaging to property and life. When such substances are soluble in water or may be condensed in contact with water or other fluids, the Capillary cell offers a simple means to establish such contact.

Aeration and Concentration of Liquids

Wherever it is desired to aerate a liquid or to concentrate a solution by means of evaporation or in any process requiring the intimate contact of a gas and a liquid, Capillary cells are worthy of investigation by chemical engineers.

Recovery

Recovery of valuable solids or liquids collected within water or other fluids passed through Capillary cells suggests the relatively simple processes of centrifuging, filtering, distillation or concentration.

Combustion Air for Engines

For test purposes or as the permanent supply of air to internal combustion engines, Diesel and gasoline, Capillary conditioners offer a means whereby *clean* air at fixed temperature and humidity can be supplied at small expense.

Condenser Water Cooling

Condensing water for steam engine, steam turbine, or refrigeration installations may be cooled within Capillary conditioners. It is suggested that the detailed requirements be submitted to Air & Refrigeration Corp. for study and recommendations.

Air and Refrigeration Corporation has considerable data available on special applications of Capillary Cells and will be pleased to cooperate with any manufacturer or industry in a study to determine the best solution for any particular problem.

SECTION 2 ·

ADAPTATION OF CAPILLARY CELLS TO AIR CONDITIONING APPARATUS

CAPILLARY conditioners are made in standard central station units ranging in capacity from 2200 cfm to 132,000 cfm designed to be erected by the contractor in conjunction with the various types of central fan and duct systems. Physical and capacity data covering these units appear on pages 14 to 17.

Self contained unit conditioners using Capillary cells and including fan, heaters, pump and other equipment housed in an insulated casing are made in capacities from 4000 cfm to 16,000 cfm. Descriptions and essential data on these units appear on pages 22 to 24.

Size and Capacity Designation

The size of all units, central station and self contained, is designated by *first* the number of cells high and *second*, by the number of cells wide. For example, a 6-4 central station unit has six cells in height arranged in three individual tiers of 2 cells each and is four cells in width. Each standard 2 cell tier is 2′6″ in height, making a height of 7′6″ above the tank for the three tiers. Since all cells are 20″ x 20″, the width for four cells is 80″.

SPECIAL FEATURES OF CAPILLARY CONDITIONERS

A study of the schematic drawings on pages 12 and 13, as well as the dimensioned drawings of the various classes of units on the following pages, will reveal to the engineer and designer the wide flexibility for their use. Certain features will also become evident which are unique in this equipment.

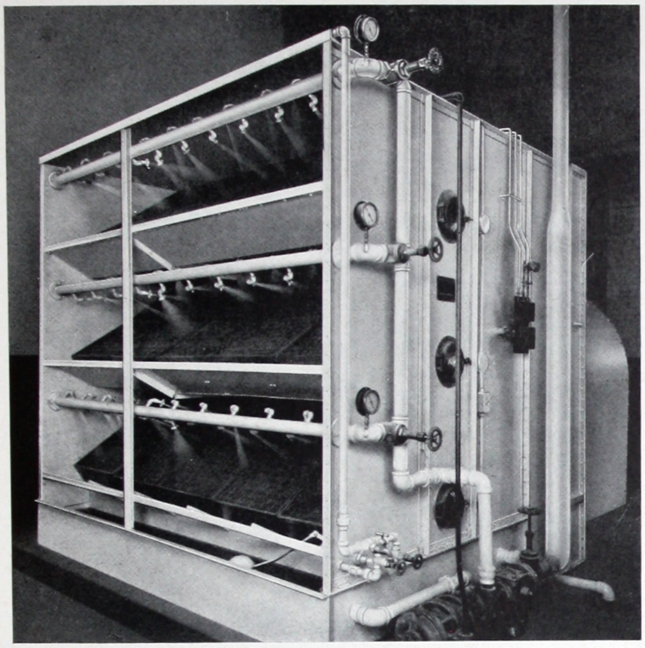
Individual Tier Distribution

One of the notable features of Capillary conditioners is the system of tiers in which cells are arranged. Each tier is, in effect, an individual conditioning unit, 30 inches in height, with independent air and water supply. The water supplied to each tier of two cells returns directly to the tank through the trough and thence to the conduit communicating with each tier. The effect is to produce uniform leaving conditions of air and water at each tier, unaffected by those above and to establish uniform resistance to air flow over the whole unit.

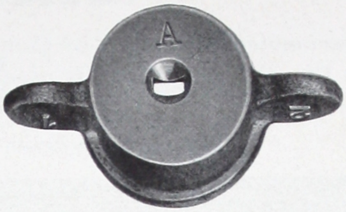
This is in contrast to a spray type dehumidifier of any considerable height wherein the water atomized by the upper spray nozzles having been warmed by the air, falls and mixes with the water issuing from the lower nozzles. The result is uneven resistance to air flow from top to bottom of the dehumidifier, uneven leaving dew point temperature and stratification.

Eliminators

The fact that water supplied to Capillary conditioners is at low nozzle pressure and not finely atomized and the fact that water leaving the cell is recollected into large drops on the horizontal filaments at the leaving face, makes elimination of entrained moisture extremely simple.



A standard Size 6-5 Class I Capillary Central Station Installation. Nominal capacity 30,000 cfm.



A special nozzle has been developed for the distribution of water over Capillary Cells. The large orifice makes these nozzles relatively free from clogging and the rectangular shape of the orifice creates a spray pattern suited to the cell face area.

NOZZLE CAPACITIES — G.P.M.

	Pressure — Lbs.				
Size	4	6	8	10	12
A	0.99	1.22	1.42	1.60	1.75
B	1.83	2.26	2.63	2.95	3.23
C	2.04	2.50	2.90	3.25	3.57

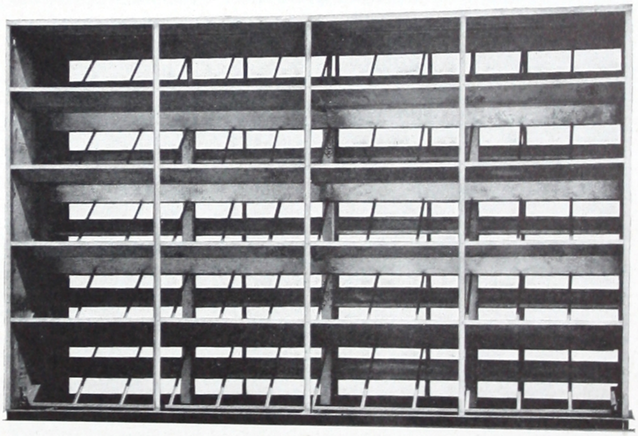
Glass Mat Eliminators

In Class I Capillary units, wherein the sprays are located at the entering face of the cells, entrainment may be entirely eliminated by simple glass mats arranged as shown in the illustrations. Glass mats are made up of glass filaments arranged in a relatively open mat approximately one inch in thickness, the filaments being permanently bonded into mat formation by a light latex treatment. Each mat 20″ x 20″ in face area is set in a galvanized metal frame and a 2″ mesh galvanized screen covers each face.

Whereas the usual forms of metal eliminators are the first part of a washer to corrode and must be removed for cleaning and painting, there is little to corrode on a glass mat eliminator. The mats are easily removed to give clear access to the casing interior.

Metal Eliminators

It is necessary to use metal eliminator plates on Class II Capillary units where the sprays are arranged at the leaving face of the cells. Again, however, since the sprays operate at low pressure, the spray is not fine and elimination of entrained water is simple. The eliminator plates have only two simple bends and two water collecting lips. They are approximately seven inches in depth and are set on $1\frac{1}{8}$-inch centers. Each plate is individually removable.



The casing, internal cell supports, troughs and conduits for a standard Size 10-12 Class I Capillary Conditioner. Nominal capacity 120,000 cfm.

Tank

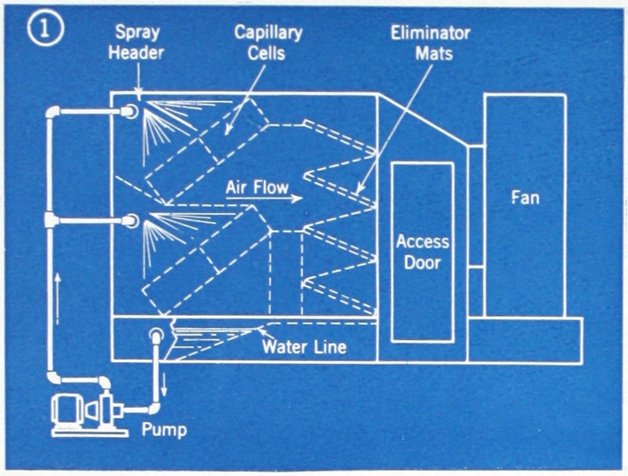
The collecting tank on standard central station Capillary units is welded of 10-gauge steel plate. The sloping bottom facilitates flushing and cleaning and largely reduces the weight of water to be carried in the tank.

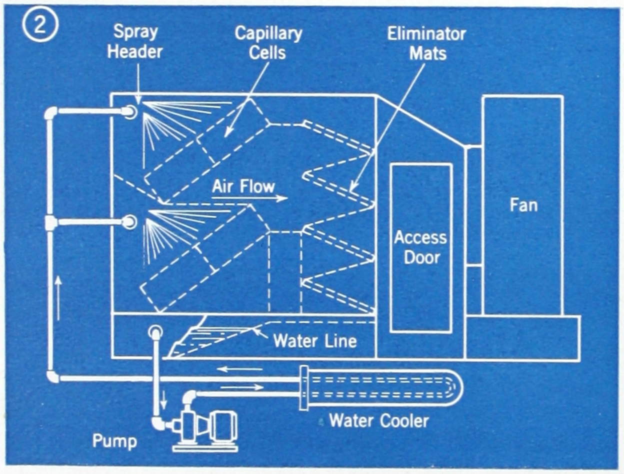
Length of Units

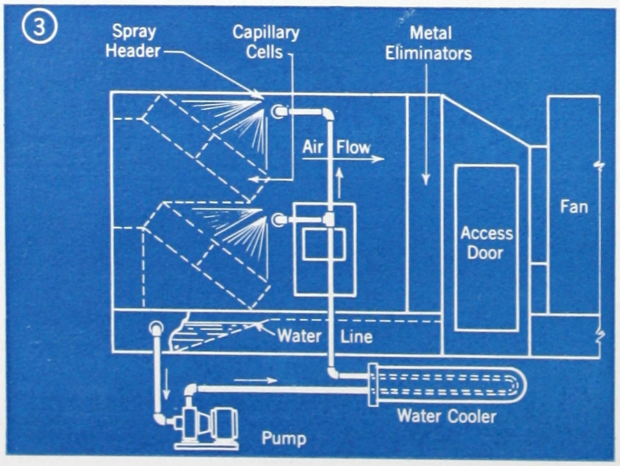
It will be found by comparison that spray type humidifiers or dehumidifiers cannot approach Capillary conditioners in humidifying or heat transfer performance within the same length of air travel. The answer, of course, is the efficiency of contact effected within the short space occupied by a single bank of cells.

CLASS DESIGNATION

The various arrangements of Capillary cells with reference to air and water flow are designated as Classes ● *Class I is used to indicate the concurrent flow of water and air through the cell* ● *Class II indicates counterflow of air and water through the cell* ●







❶ Class I Capillary Conditioners

As a simple air washer, humidifier or evaporative cooler, the Class I Capillary conditioner using concurrent flow of air and water, is usually applied. For these applications the units are usually selected for the full air capacity ranging up to 1100 cfm per cell maximum. It is to be noted that the pump simply recirculates the water from the tank over the Capillary cells.

As stated previously, 3 gallons of water per cell per minute is required at 6 pound nozzle pressure. The total required pumping head, including friction loss, is 22½ ft. plus the height of the unit above the tank or 2½ ft. per tier of two cells.

❷ Class I Capillary as Cooler and Dehumidifier

The Class I Capillary, using concurrent flow of water and air may be used as a cooler and dehumidifier through the application of cold water over the cells. The opposite illustration shows the pump drawing water from the tank and passing it through a cooler, thence to the Capillary cells.

Cold water from wells or other sources may be used, in which case various methods of by-passing or working in series with the usual recirculation pump may be applied.

Performance of the Class I Capillary may be determined through the use of the chart on page 20. In general the performance will approximate that of a 2 bank spray type dehumidifier.

❸ Class II Capillary Conditioners

The Class II Capillary Conditioner wherein the Air Flow through the cell is counter to that of the water, is recommended for washing when exceptionally heavy dust concentration is carried by the entering air and for cooling and dehumidifying where it is desired to obtain a somewhat nearer approach between leaving water and leaving air than results in concurrent flow through the Class I Capillary. With proper proportioning of the air and water quantities passing through the cells in the Class II arrangement, an approach between leaving air and leaving water of less than 1° may usually be obtained.

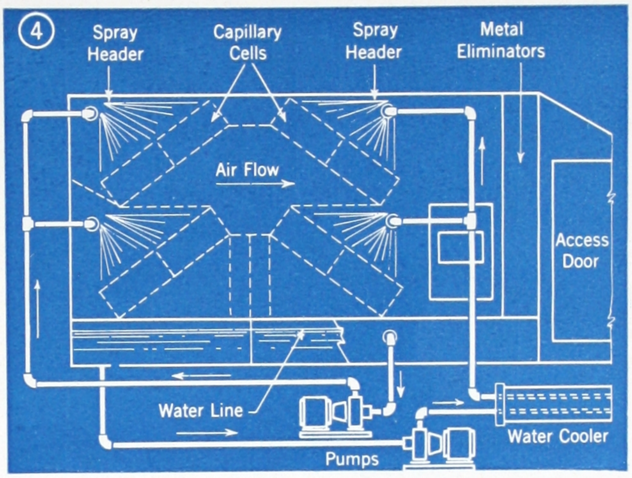
AND ARRANGEMENTS

Class I-II *represents the use of Class I and Class II arrangement of cells in series as two banks or two stages to meet special heat transfer requirements* ● **Class III** *involves the use of various forms of cooling coils, direct expansion or cold water, in conjunction with and as a part of Capillary conditioners* ● *All of these arrangements are discussed and illustrated by schematic drawings below* ●

4 Class I-II Capillary Conditioner

The 2 Bank arrangement is used when it is desired to use water quantities in excess of the maximum of 9 gals. per cell in which case the water is divided between the 2 Banks. This method may be applied where the air is used to cool water for condensing purposes or other uses or, where it is desired to achieve a rise in water temperature not obtainable with a single bank.

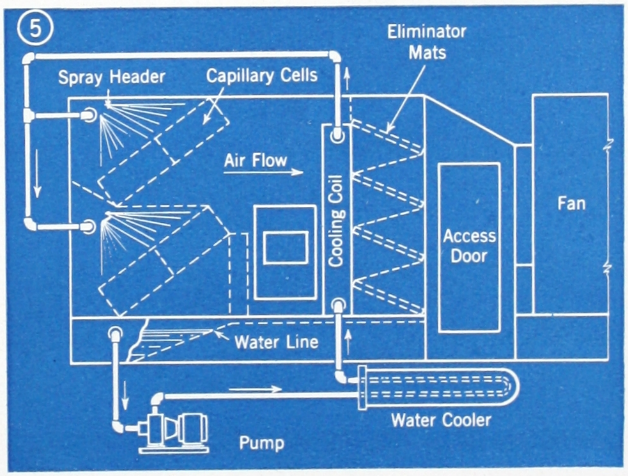
The 2 Stage arrangement is used where it is desired to obtain a considerable rise in water temperature. This arrangement calls for the delivery of the full water quantity to the 2nd stage of cells. The water then passes to the tank and is picked up by a second pump and passed through the 1st stage of cells. Through this method it is possible to achieve from 12 to 16 degrees rise in the water with the leaving water temperature in excess of that of the leaving air.



5 Class III Capillary Conditioners

These units involve the use of cooling coils incorporated in the casing of the Capillary unit. Such coils may be for direct expansion refrigeration or for the circulation of cold liquids.

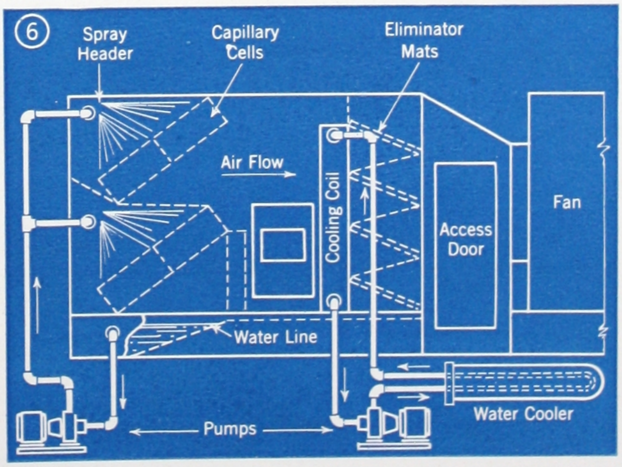
Illustration (5) shows the Class III arrangements where the cooling water is passed first through the coil then over the Capillary cells. This arrangement offers counter flow performance as in a 2 stage Capillary. Whereas a coil ranging from 6 to 12 rows in depth may be required to obtain a desired water temperature rise, the capillary cells may be used after the water has left the coil to carry from 50 to 75 per cent of the load and thus reduce the number of rows of coils correspondingly.



6 Class III with Closed Circuit Coil

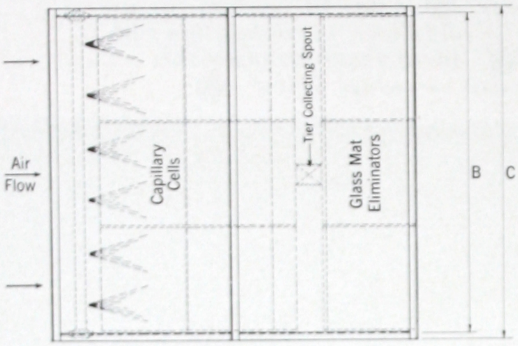
The closed circuit of cooling fluid shown in illustration (6) is applied where direct expansion is applied or where, for some reason, the water or brine circuit may not be opened.

In each instance the Capillary in advance of the coil keeps the coil clean, provides the economy of evaporative cooling when entering wet-bulb conditions permit, offers year-round humidity control.

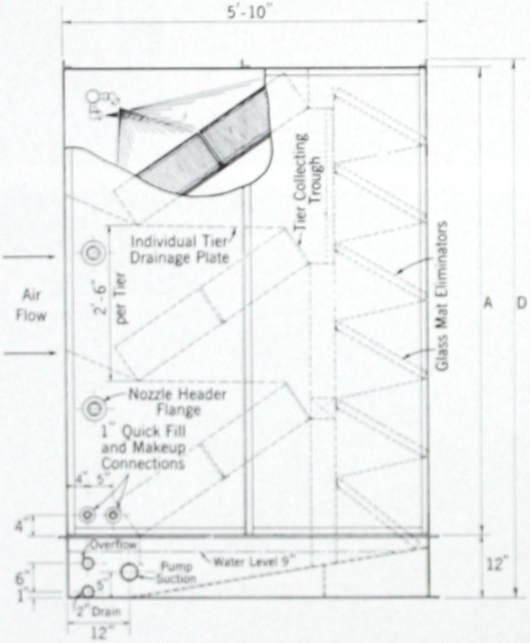


CLASS I CAPILLARY CONDITIONERS

With Glass Mat Eliminators

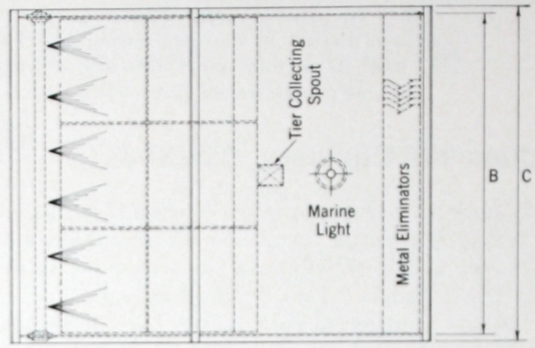


PLAN



SIDE ELEVATION

With Metal Eliminators



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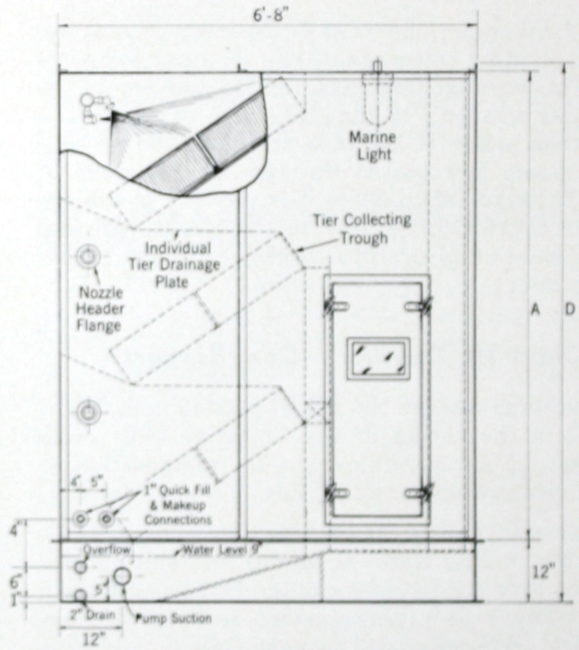


SIDE ELEVATION

Specification

Tank:

Welded steel 10 ga. U.S.S. with welded suction, drain and overflow fittings, standard pipe thread. Painted; inside, 2 coats of bitumastic; outside, ground coat.

Casing:

Sides and top 18 ga. galv. steel reinforced with 1½" x 1½" x ⅛" galv. angles up to and including 6 cells high or 6 cells wide. Above these limits 2" x 2" x ⅛" angles are used.

Eliminators:

Metal; 24 ga. galv. steel, 8" deep spaced at 1⅛" centers.

Glass mat; 20" x 20" by 2" nominal depth. Casing 26 ga. galv. iron. Screens—No. 12 B.W.G. steel wire, hot dipped galvanized.

Capillary Cells:

20" x 20" x 8" nominal depth.

Casing—26 ga. galv. iron.

Screens—No. 12 B.W.G. steel wire—hot dipped galvanized.

Internal Safings:

Tier drains and troughs; 14 ga. galv. steel.

Spray Headers:

Galv. Steel Pipe.

Spray Nozzles:

Bronze.

Strainer:

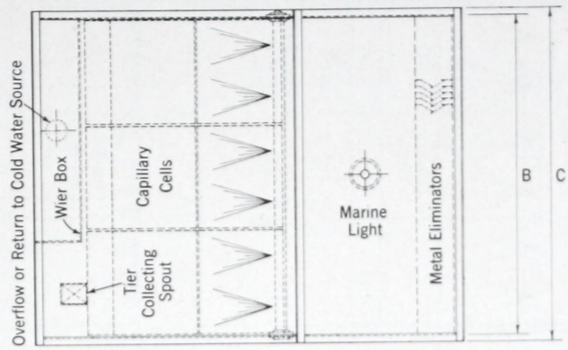
External type with bronze screen bucket.

Constant Level Float Valve, ¾".

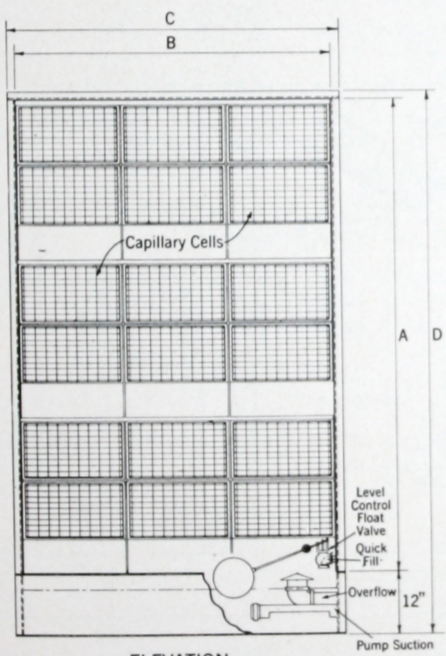
CLASS II CAPILLARY CONDITIONERS
With Metal Eliminators

NOTE

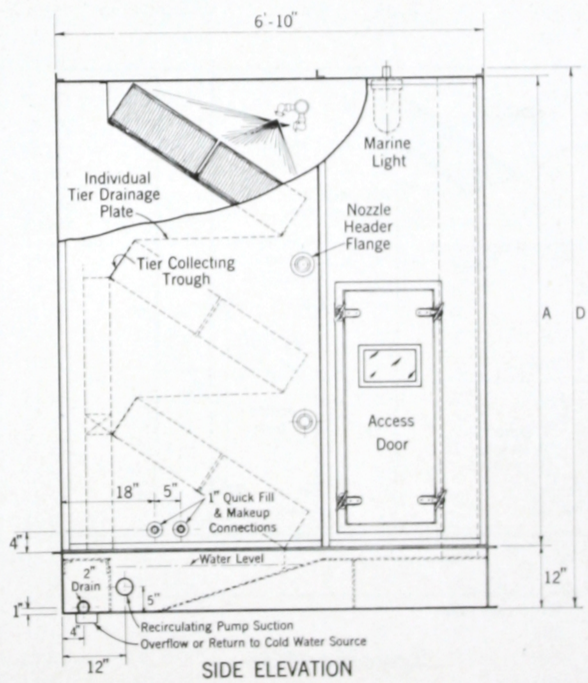
Class II Capillaries are not furnished with Glass Mat Eliminators.



PLAN



ELEVATION
ENTERING FACE



SIDE ELEVATION

Specification

Tank:
Welded steel 10 ga. U.S.S. with welded suction, drain and overflow fittings, standard pipe thread. Painted; inside, 2 coats of bitumistic; outside, ground coat.

Casing:
Sides and top 18 ga. galv. steel reinforced with $1\frac{1}{2}'' \times 1\frac{1}{2}'' \times \frac{1}{8}''$ galv. angles up to and including 6 cells high or 6 cells wide. Above these limits $2'' \times 2'' \times \frac{1}{8}''$ angles are used.

Eliminators:
Metal; 24 ga. galv. steel, 8″ deep spaced at $1\frac{1}{8}''$ centers.

Capillary Cells:
20″ x 20″ x 8″ nominal depth.
Casing—26 ga. galv. iron.
Screens—No. 12 B.W.G. steel wire—hot dipped galvanized.

Internal Safings:
Tier drains and troughs; 14 ga. galv. steel.

Spray Headers:
Galv. Steel Pipe.

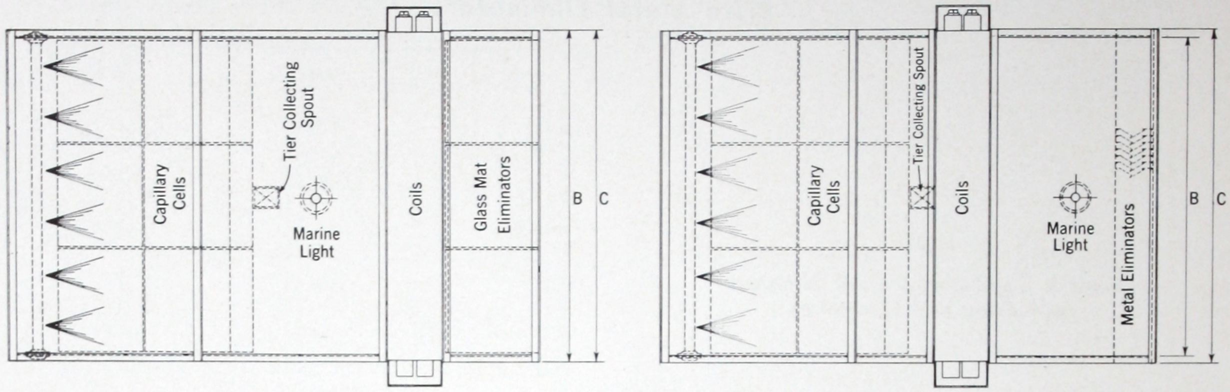
Spray Nozzles:
Bronze.

Strainer:
External type with bronze screen bucket.

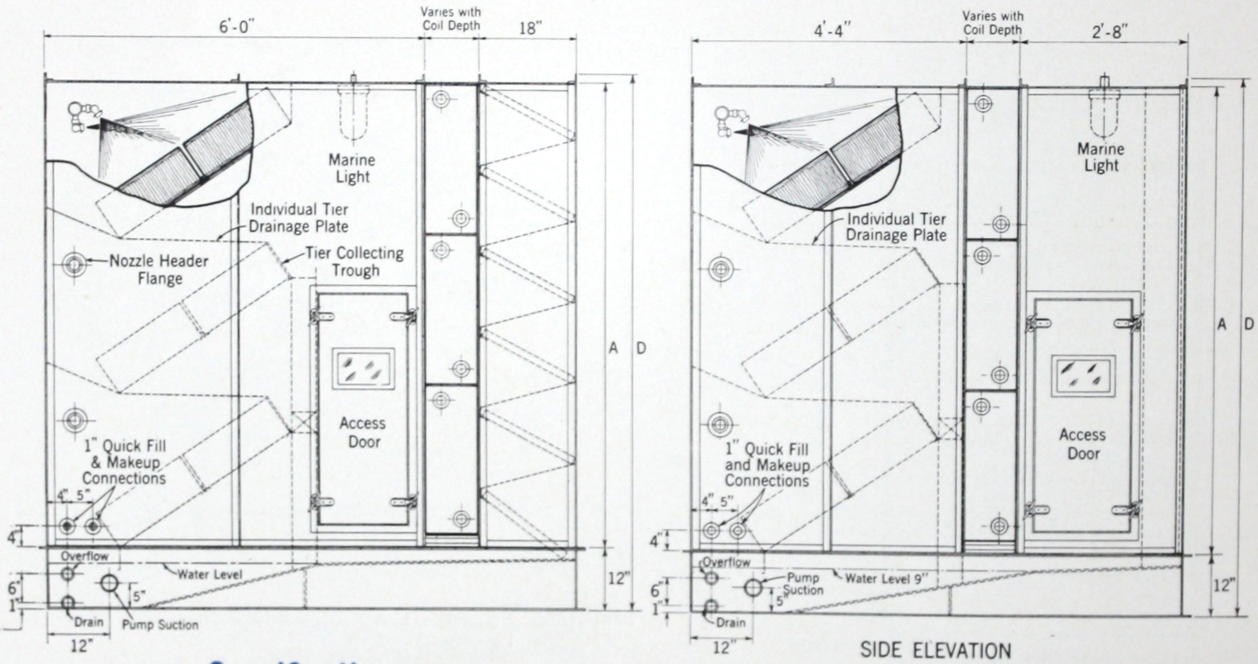
Constant Level Float Valve, ¾″.

CLASS III CAPILLARY CONDITIONERS

With Glass Mat Eliminators — **With Metal Eliminators**



PLAN



SIDE ELEVATION

Specification

Tank:
Welded steel 10 ga. U.S.S. with welded suction, drain and overflow fittings, standard pipe thread. Painted; inside, 2 coats of bitumastic; outside, ground coat.

Casing:
Sides and top 18 ga. galv. steel reinforced with 1½" x 1½" x ⅛" galv. angles up to and including 6 cells high or 6 cells wide. Above these limits 2" x 2" x ⅛" angles are used.

Eliminators:
Metal; 24 ga. galv. steel, 8" deep spaced at 1⅛" centers.
Glass mat; 20" x 20" by 2" nominal depth. Casing 26 ga. galv. iron. Screens—No. 12 B.W.G. steel wire, hot dipped galvanized.

Capillary Cells:
20" x 20" x 8" nominal depth.
Casing—26 ga. galv. iron.
Screens—No. 12 B.W.G. steel wire—hot dipped galvanized.

Internal Safings:
Tier drains and troughs; 14 ga. galv. steel.

Spray Headers:
Galv. Steel Pipe.

Spray Nozzles:
Bronze.

Strainer:
External type with bronze screen bucket.

Constant Level Float Valve, ¾".

Coils:
Finned tubes selected to meet specific requirements.

STANDARD DIMENSION AND CAPACITY TABLE

SIZE Cells High x Cells Wide	C.F.M. MAXIMUM	SHIPPING WEIGHTS CLASS I Glass Mat Eliminators Pounds	SHIPPING WEIGHTS CLASS I Metal Eliminators Pounds	SHIPPING WEIGHTS CLASS II Metal Eliminators Pounds	A Height Above Tank	B Inside Width	C Overall Width	D Overall Height	★ SIZE OF SPRAY HEADERS	SIZE OF DRAIN CONNECTION	G.P.M. MINIMUM	G.P.M. MAXIMUM
2 x 2	4,400	920	1,023	1,048	2′6″	3′4″	3′ 7⅛″		2″	2″	12	36
2 x 3	6,600	1,167	1,308	1,338	2′6″	5′0″	5′ 3⅛″		2″	2″	18	54
2 x 4	8,800	1,439	1,618	1,653	2′6″	6′8″	6′11⅛″	3′7½″	2″	2″	24	72
2 x 5	11,000	1,696	1,913	1,953	2′6″	8′4″	8′ 7⅛″		2″	2″	30	90
2 x 6	13,200	1,943	2,198	2,243	2′6″	10′0″	10′ 3⅛″		2″	2″	36	108
2 x 7	15,400	2,248	2,541	2,591	2′6″	11′8″	12′ 0⅛″		2″	2″	42	126
2 x 8	17,600	2,495	2,826	2,881	2′6″	13′4″	13′ 8⅛″		2″	2″	48	144
2 x 9	19,800	2,742	3,111	3,171	2′6″	15′0″	15′ 4⅛″	3′8″	2″	2″	54	162
2 x 10	22,000	3,024	3,431	3,496	2′6″	16′8″	17′ 0⅛″		2″	2″	60	180
2 x 11	24,200	3,271	3,716	3,786	2′6″	18′4″	18′ 8⅛″		2″	2″	66	198
2 x 12	26,400	3,518	4,001	4,076	2′6″	20′0″	20′ 4⅛″		2″	2″	72	216
4 x 2	8,800	1,330	1,505	1,540	5′0″	3′4″	3′ 7⅛″		2″	2″	24	72
4 x 3	13,200	1,704	1,945	1,985	5′0″	5′0″	5′ 3⅛″		2″	2″	36	108
4 x 4	17,600	2,138	2,445	2,490	5′0″	6′8″	6′11⅛″	6′1½″	2″	2″	48	144
4 x 5	22,000	2,522	2,895	2,945	5′0″	8′4″	8′ 7⅛″		2″	2″	60	180
4 x 6	26,400	2,896	3,335	3,390	5′0″	10′0″	10′ 3⅛″		2″	2″	72	216
4 x 7	30,800	3,363	3,868	3,928	5′0″	11′8″	12′ 0⅛″		2″	2″	84	252
4 x 8	35,200	3,735	4,306	4,371	5′0″	13′4″	13′ 8⅛″		2″	2″	96	288
4 x 9	39,600	4,111	4,748	4,818	5′0″	15′0″	15′ 4⅛″	6′2″	2″	2″	108	324
4 x 10	44,000	4,545	5,248	5,323	5′0″	16′8″	17′ 0⅛″		2″	2″	120	360
4 x 11	48,400	4,929	5,698	5,778	5′0″	18′4″	18′ 8⅛″		2″	2″	132	396
4 x 12	52,800	5,303	6,138	6,223	5′0″	20′0″	20′ 4⅛″		2″	2″	144	432
6 x 2	13,200	1,750	1,997	2,037	7′6″	3′4″	3′ 7⅛″		2″	2″	36	108
6 x 3	19,800	2,261	2,602	2,647	7′6″	5′0″	5′ 3⅛″		2″	2″	54	162
6 x 4	26,400	2,847	3,282	3,332	7′6″	6′8″	6′11⅛″	8′7½″	2″	2″	72	216
6 x 5	33,000	3,348	3,877	3,932	7′6″	8′4″	8′ 7⅛″		2″	2″	90	270
6 x 6	39,600	3,859	4,482	4,542	7′6″	10′0″	10′ 3⅛″		2″	2″	108	324
6 x 7	46,200	4,478	5,195	5,260	7′6″	11′8″	12′ 0⅛″		2″	2″	126	378
6 x 8	52,800	4,979	5,790	5,860	7′6″	13′4″	13′ 8⅛″		2″	2″	144	432
6 x 9	59,400	5,490	6,395	6,470	7′6″	15′0″	15′ 4⅛″	8′8″	2″	2″	162	486
6 x 10	66,000	6,076	7,075	7,155	7′6″	16′8″	17′ 0⅛″		2″	2″	180	540
6 x 11	72,600	6,582	7,675	7,760	7′6″	18′4″	18′ 8⅛″		2″	2″	198	594
6 x 12	79,200	7,088	8,275	8,365	7′6″	20′0″	20′ 4⅛″		2″	2″	216	648
8 x 3	26,400	2,798	3,239	3,294	10′0″	5′0″	5′ 4⅛″		2″	2″	72	216
8 x 4	35,200	3,546	4,109	4,169	10′0″	6′8″	7′ 0⅛″		2″	2″	96	288
8 x 5	44,000	4,184	4,869	4,934	10′0″	8′4″	8′ 8⅛″		2″	2″	120	360
8 x 6	52,800	4,822	5,629	5,699	10′0″	10′0″	10′ 4⅛″		2″	2″	144	432
8 x 7	61,600	5,593	6,522	6,597	10′0″	11′8″	12′ 0⅛″	11′2″	2″	2″	168	504
8 x 8	70,400	6,231	7,282	7,362	10′0″	13′4″	13′ 8⅛″		2″	2″	192	576
8 x 9	79,200	6,859	8,032	8,117	10′0″	15′0″	15′ 4⅛″		2″	2″	216	648
8 x 10	88,000	7,607	8,902	8,992	10′0″	16′8″	17′ 0⅛″		2″	2″	240	720
8 x 11	96,800	8,245	9,662	9,757	10′0″	18′4″	18′ 8⅛″		2″	2″	264	792
8 x 12	105,600	8,883	10,422	10,522	10′0″	20′0″	20′ 4⅛″		2″	2″	288	864
10 x 3	33,000	3,467	4,017	4,082	12′6″	5′0″	5′ 4⅛″		2″	2″	90	270
10 x 4	44,000	4,368	5,068	5,138	12′6″	6′8″	7′ 0⅛″		2″	2″	120	360
10 x 5	55,000	5,139	5,989	6,064	12′6″	8′4″	8′ 8⅛″		2″	2″	150	450
10 x 6	66,000	5,908	6,908	6,988	12′6″	10′0″	10′ 4⅛″		2″	2″	180	540
10 x 7	77,000	6,844	7,994	8,089	12′6″	11′8″	12′ 0⅛″	13′8″	2″	2″	210	630
10 x 8	88,000	7,614	8,914	9,004	12′6″	13′4″	13′ 8⅛″		2″	2″	240	720
10 x 9	99,000	8,384	9,834	9,929	12′6″	15′0″	15′ 4⅛″		2″	2″	270	810
10 x 10	110,000	9,299	10,899	10,999	12′6″	16′8″	17′ 0⅛″		2″	3″	300	900
10 x 11	121,000	10,059	11,809	11,914	12′6″	18′4″	18′ 8⅛″		2″	3″	330	990
10 x 12	132,000	10,749	12,649	12,759	12′6″	20′0″	20′ 4⅛″		2″	3″	360	1,080

★ Spray headers specified are for minimum water quantities.

SECTION 3 •

ENGINEERING AND PERFORMANCE DATA FOR CAPILLARY AIR CONDITIONERS

THE charts on pages 20 and 21 present a convenient method for the graphic solution of heat transfer problems in the Capillary cells. These charts were derived from an exhaustive series of tests under controlled and standardized laboratory conditions for the Class I and Class II arrangement of Capillary cells.

The skeleton chart on page 19 indicates the direction lines employed in solving a problem on the charts.

Example I

Assume a mixture of outdoor and return air amounting to 1000 cfm per cell to be cooled from 80° dry bulb and 70° wet bulb to a dew point of 58° leaving the cell. Chilled water is available at 45°. *Find* the gpm per cell required and the rise in water temperature, alternately for Class I and Class II Capillaries.

Solution

Total heat per lb. of air at 70° entering wet bulb = 34 BTU/LB
Total heat per lb. of air at 58° leaving dew point = 25.2 " "
8.8 " "

$$\frac{\text{1000 cfm cell}}{\text{Weight of air 13.9 cu ft/lb}} = \text{72 lbs per min per cell}$$

72 lbs/cell x 8.8 BTU/LB x 60 min = 38,000 BTU/HR required capacity of cell.

Referring to the Class I and Class II performance charts.

1. Project a line from 45° entering water at the right hand side of chart to the 70° entering wet bulb line.
2. From the above intersection drop a vertical line down to the horizontal reference line.
3. From this intersection follow a constant ratio line until it intersects with a vertical line projected vertically from 38,000 BTU/HR (the required capacity) on the base line.
4. From this intersection project a horizontal line to the left to intersect with the curve for 1000 cfm per cell.
5. From this intersection drop a vertical line to the gpm per cell base line which shows 8.3 gpm per cell required for Class I and 6.8 gpm per cell required for Class II.

$$\text{Water Temp. rise Class I; } \frac{\text{38,000 BTU/HR}}{\text{8.3 gpm x 8.33 x 60}} = 9.16°$$

$$\text{Class II; } \frac{\text{38,000 BTU/HR}}{\text{6.8 gpm x 8.33 x 60}} = 11.14°$$

Example II

Required to cool 1000 cfm (72 lbs/min) per cell from 80° dry bulb and 70° entering wet bulb temperature to a leaving dew point temperature of 55°. Chilled water is available at 43° and it is desired to obtain 15° rise in the water.

This problem, if solved for cooling coil requirements, in accordance with Aerofin factors, will indicate that a coil 6.6 rows in depth would be required; 7 rows would be used.

If a Class II Capillary is considered in place of the coils it will be found that the required 45,000 BTU/HR cannot be obtained with the available water quantity.

In this case, a Class III Capillary might be applied wherein the water passes first through a coil thence over the cells, while the air passes first through the cells thence through the coil. See Fig. 5, page 13.

Solution

Total heat per lb of air at entering wet bulb of 70° = 33.4
Total heat at 55° saturated = 23.0
10.4

Total load 72 lbs x 10.4 x 60 = 45,000 BTU/HR

$$\text{water quantity available: } \frac{\text{45,000 BTU/HR}}{\text{15° rise x 8.33 x 60}} = \text{6 gpm}$$

As a trial, assume that the cells will carry 60 per cent of the load. Determine from Class I performance chart whether cell has necessary capacity. If so, then determine coil depth to carry remaining 40 per cent.

If coil carries 40 per cent of load, determine temperature of water leaving coil and entering cell.

$$\frac{\text{45,000 BTU x 0.4}}{\text{6 gpm x 8.33 x 60}} = 6° \text{ rise} + 43° = 49° \text{ leaving water}$$

Air entering cell 1000 cfm at 70° W. B. water entering cell 6 gpm @ 49°. From Class I performance chart, cell capacity is found to be 27,000 BTU/HR which is 60 per cent of the total load, as required.

The remaining 40 per cent of the load to be absorbed by the coil involves the following conditions:

Total heat per lb. of air leaving cell and entering coil is:

$$33.4 - 0.6\,(33.4 - 23.0) = 27.16$$

which corresponds to 61.5° wet bulb. The air entering the coil would be saturated at this temperature and is to be cooled to 55° saturated with entering water at 43° 6 gpm per 1000 cfm.

Selection of the coil in accordance with Aerofin factors indicates that 2.5 rows in depth would be required; 3 rows would be used.

This is in contrast to 7 rows called for without the Capillary. At the same time, the Capillary cells, in advance of the coils, provide evaporative cooling at entering wet bulb temperatures at or below 55°. The Capillary replaces filters and the unit would offer less resistance than 7 row coils and filters.

Example III

Assume the same requirements as outlined in Example 2. Namely 1000 cfm (72 lbs) of air entering at 70° wet bulb to be cooled to 55° dew point. Cold water available at 43° and a rise of 15° is desired.

Apply, in place of coils, a Class I-II Capillary conditioner using 2 stage, counterflow effect. (See Fig. 4, page 13.)

Solution

Assume that the second air stage, which receives the 43° chilled water carries 55 per cent of the load.

0.55 x 45,000 BTU/HR = 24,800 BTU/HR required capacity of 2nd stage cell.

0.45 x 45,000 BTU/HR = 20,200 BTU/HR required capacity of 1st stage cell.

$$\frac{20{,}200 \text{ BTU/HR}}{72 \text{ lbs air/min} \times 60} = 4.68 \text{ BTU/per lb of air extracted in first stage.}$$

Total heat of air at 70° entering wet bulb, 33.4 BTU/lb. minus 4.68 BTU/lb. equals 28.72 BTU/lb., which corresponds to 63.8° wet bulb temperature leaving the 1st stage and entering the 2nd stage.

Water entering 2nd stage 6 gpm at 43°.

Water leaving 2nd stage and entering 1st stage:

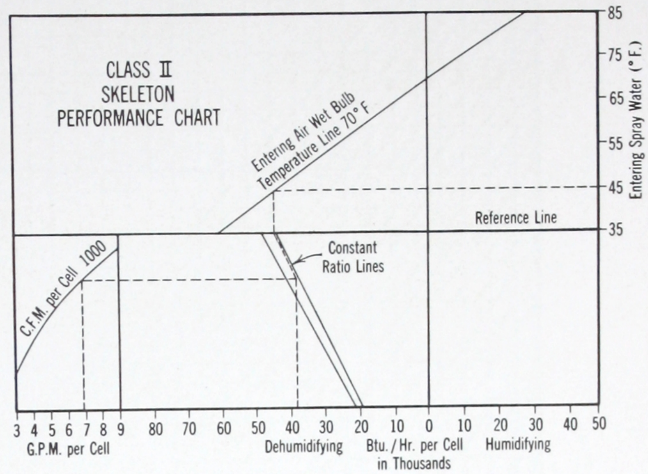
$$\frac{24{,}800 \text{ BTU/HR}}{6 \text{ gpm} \times 8.33 \times 60} = 8.26° \text{ rise} + 43° = 51.26°$$

Water leaving 1st stage:

$$\frac{20{,}200 \text{ BTU/HR}}{6 \text{ gpm} \times 8.33 \times 60} = 6.74° + 51.26° = 58°$$

From the Class I performance chart for the 1st stage: entering water 6 gpm at 51.26°, 1000 cfm at 70° entering wet bulb, 23,000 BTU/hr/cell is available, which is more than adequate, 20,200 BTU/hr being required.

From the Class II performance chart for the 2nd stage: entering water 6 gpm at 43°, 1000 cfm at 63.8° entering wet bulb 28,000 BTU/hr/cell is available, which is more than adequate, 24,800 BTU/hr being required.



AIR RESISTANCE, INCHES WATER GAUGE, CLASS I CAPILLARY CONDITIONERS WITH EITHER GLASS MAT OR METAL ELIMINATORS

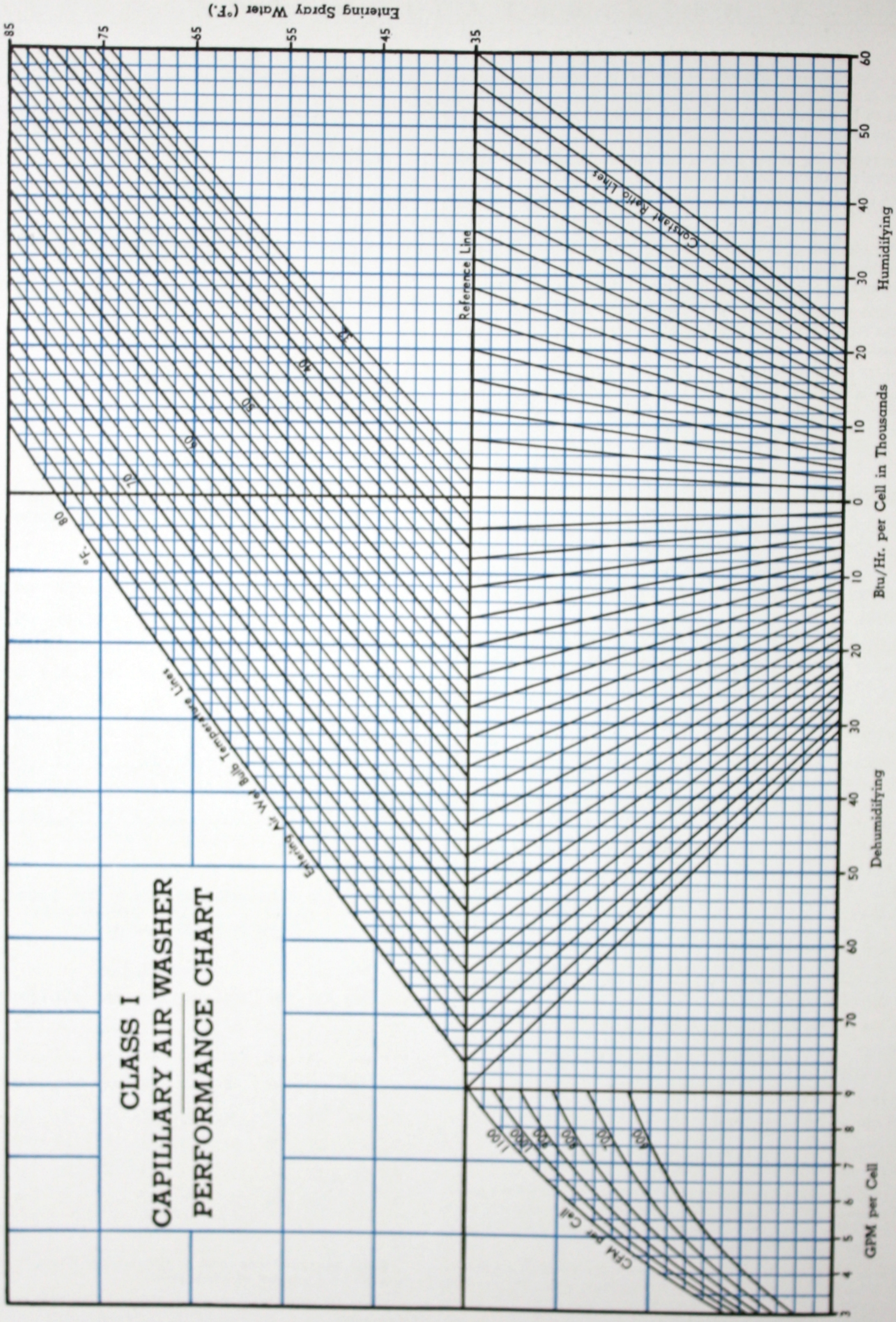
GPM per Cell	CFM per Cell 600	650	700	750	800	850	900	950	1000	1050	1100
3	.14	.16	.18	.20	.23	.25	.28	.31	.34	.37	.40
4	.14	.16	.18	.21	.23	.26	.29	.32	.35	.38	.41
5	.14	.16	.19	.21	.24	.27	.29	.32	.36	.39	.42
6	.14	.17	.19	.22	.24	.27	.30	.33	.36	.40	.43
7	.15	.17	.19	.22	.25	.28	.31	.33	.37	.40	.43
8	.15	.17	.20	.22	.25	.28	.31	.34	.38	.41	.44
9	.15	.18	.20	.23	.26	.29	.32	.35	.39	.42	.45

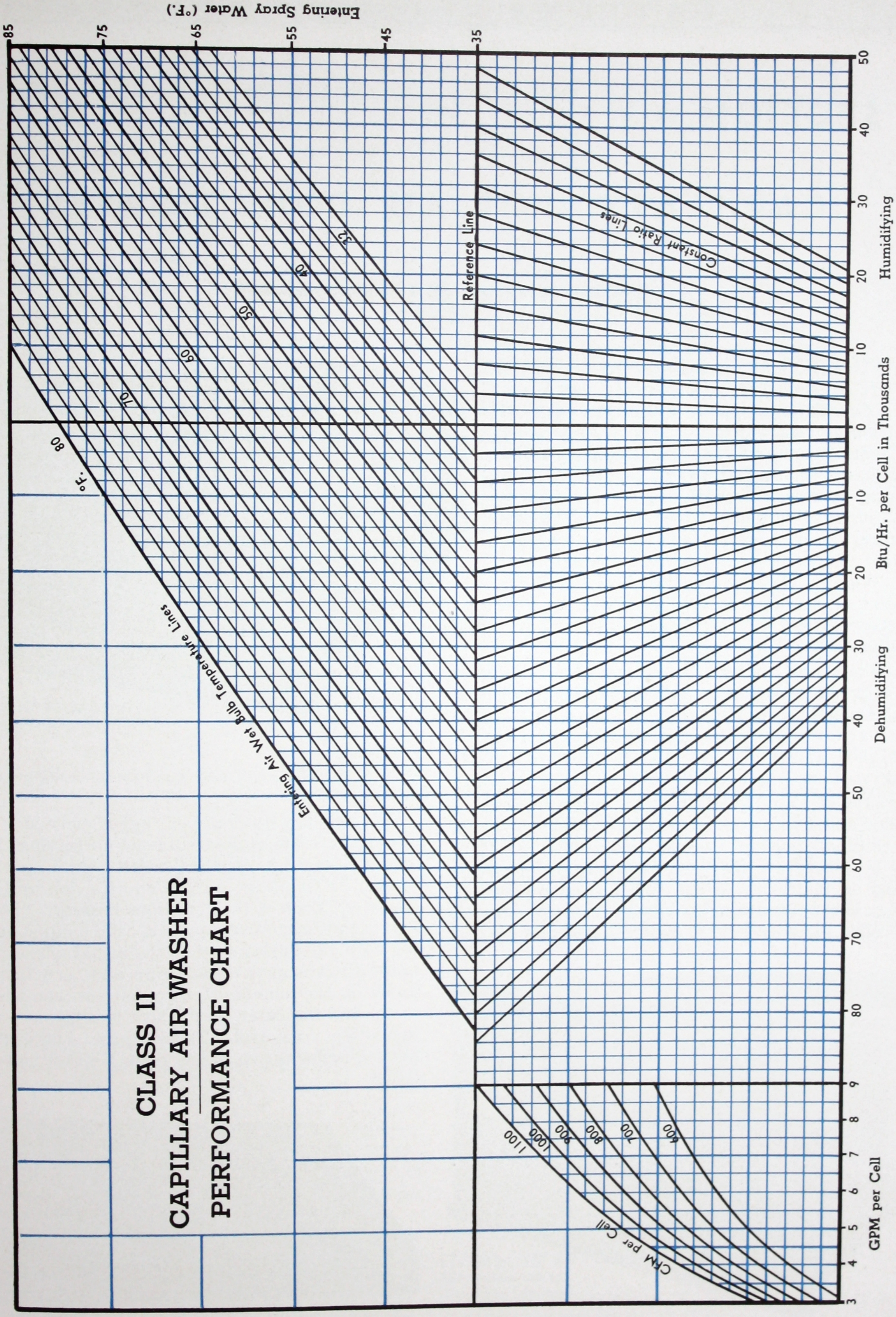
AIR RESISTANCE, INCHES WATER GAUGE, CLASS II CAPILLARY CONDITIONERS WITH METAL ELIMINATORS

GPM per Cell	CFM per Cell 600	650	700	750	800	850	900	950	1000	1050	1100
3	.19	.21	.24	.26	.29	.32	.35	.38	.42	.45	.49
4	.21	.23	.26	.29	.33	.36	.39	.43	.47	.50	.54
5	.22	.25	.28	.31	.35	.38	.42	.46	.50	.54	.58
6	.23	.26	.29	.33	.36	.40	.44	.48	.52	.56	.61
7	.24	.27	.30	.34	.38	.42	.46	.50	.55	.59	.63
8	.25	.28	.32	.36	.40	.44	.48	.52	.57	.62	.66
9	.26	.30	.34	.38	.42	.46	.51	.55	.60	.65	.70

Class I-II resistance: sum of Class I and Class II resistances less 0.1" for one set of eliminators.

Class III resistance: same as Class I plus wet resistance of coil used.

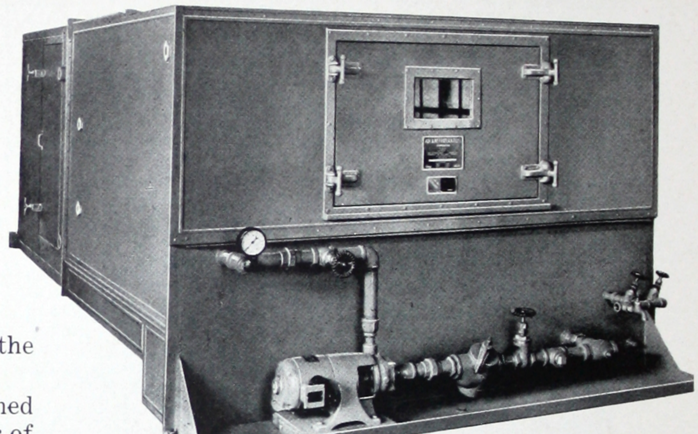

CLASS I
CAPILLARY AIR WASHER
PERFORMANCE CHART
Entering Spray Water (°F.)
85
75
65
55
45
35
Reference Line
Constant Ratio Lines
Entering Air Wet Bulb Temperature Lines
°F. 80
CFM per Cell
GPM per Cell
Btu/Hr. per Cell in Thousands
Dehumidifying
Humidifying


CLASS II
CAPILLARY AIR WASHER
PERFORMANCE CHART
Entering Spray Water (°F.)
85
75
65
55
45
35
Entering Air Wet Bulb Temperature Lines
°F. 80
70
60
50
40
32
Reference Line
Constant Ratio Lines
CFM per Cell
1100
1000
900
800
700
600
GPM per Cell
3
4
5
6
7
8
9
Btu/Hr. per Cell in Thousands
Dehumidifying
Humidifying
80
70
60
50
40
30
20
10
0
10
20
30
40
50

SECTION 4 ·

CAPILLARY UNIT AIR CONDITIONERS

CAPILLARY unit air conditioners present, in pre-assembled form, a complete central station air conditioning plant. Unlike the usual air conditioning unit which provides filters, cooling and heating coils and fan, the Capillary units combine with these features thorough air washing, evaporative cooling, heating and humidification. Supplied with cold water directly through the sprays, the Capillary cells serve as a highly efficient surface for cooling and dehumidification. Where a closed water circuit or direct expansion of refrigerant are required, the unit may be provided with a cooling coil located after the Capillary cells.

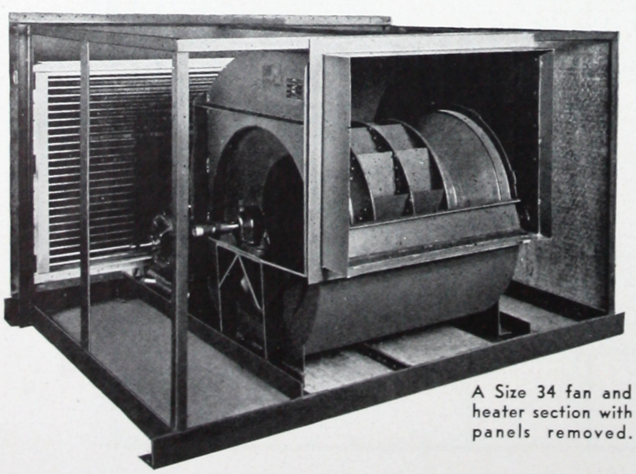


A standard Size 3-4 Capillary Unit Air Conditioner, capacity 16,000 cfm.

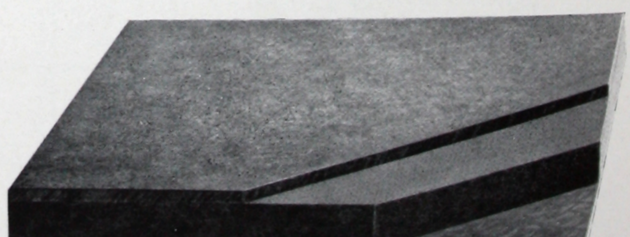
Capillary unit air conditioners have been designed in a range of capacities to meet the largest number of requirements for individual units. The sizes 2-2, 2-3, and 2-4 have maximum capacities respectively of 4800, 7500, and 10,000 cfm. The 3-4 unit has a maximum rated capacity of 16,000 cfm.

Groups of Capillary units have, in many cases, a decided advantage over large central station systems and eliminate much of the overhead duct work. They may be placed on the floor, mounted on legs, supported on platforms or suspended from ceilings or roofs. When used singly, Capillary units may be controlled like any central station apparatus. When used in groups, each unit constitutes a separate zone of control.

All Capillary units are of rugged construction and are subjected to rigid tests prior to leaving the factory. Each unit consists of two main parts, the washer or Capillary section and the fan and heater chamber. Each of these sections is factory insulated, the insulation consisting of a special laminated paneling with galvanized steel on the inside where exposed to the air stream or water spray, and hard fiber board finish on the outside. Interposed between the sheet metal and the outer fiber board is a layer of fibrous insulation material. These three materials are bonded under pressure and form a sturdy monolithic panel.

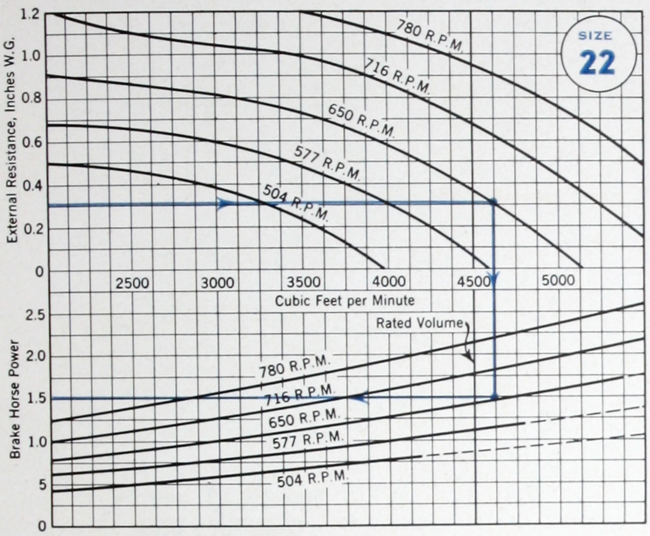


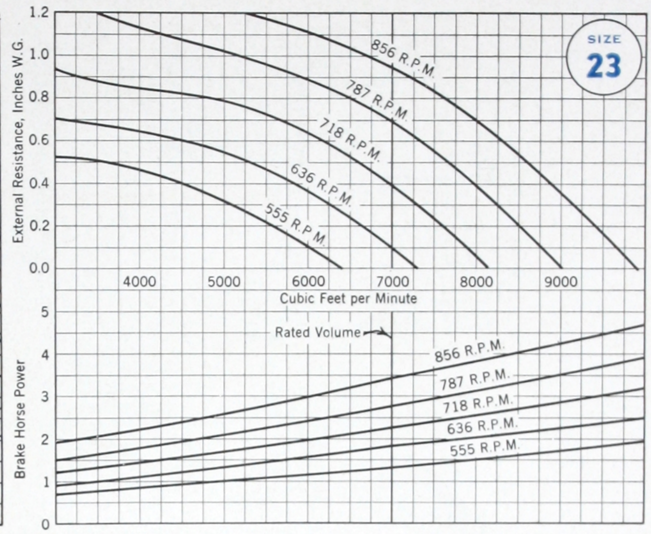
A Size 34 fan and heater section with panels removed.

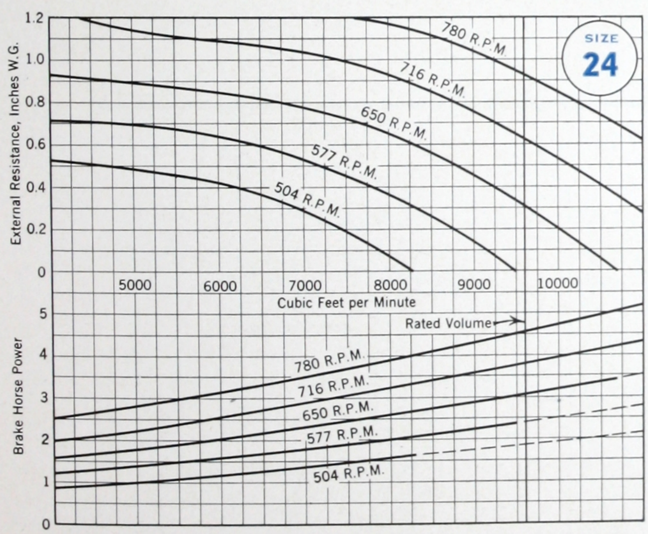


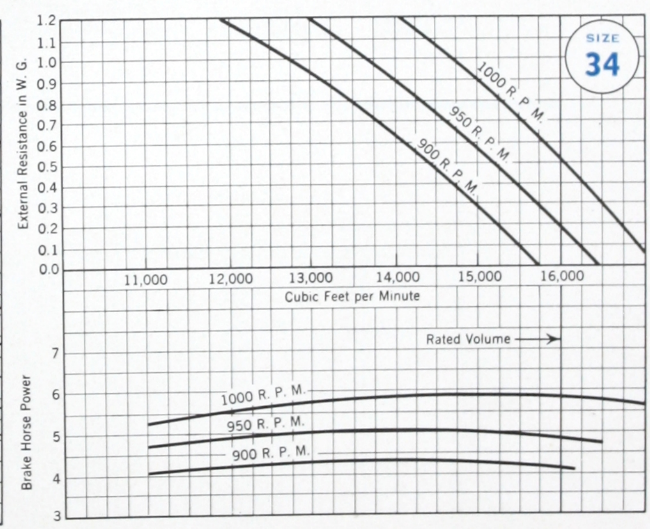
A piece of the standard insulating panel.

CAPACITY AND POWER CURVES FOR CAPILLARY UNIT AIR CONDITIONERS







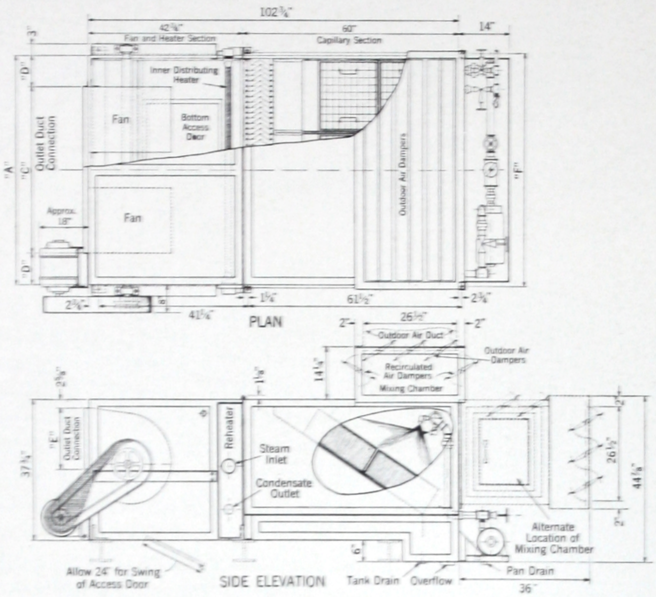


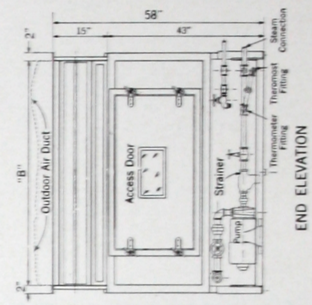
The Capillary section is complete with tank, Capillary cells, spray nozzles, circulating pump, water piping, water level control, drain and overflow connections and eliminators. The tank is of 10 Gauge black steel, welded construction and forms, together with the welded steel pan beneath the pump and exterior piping, a sturdy sub-base for supporting the unit. The entire frame work for supporting the insulated panel casing is welded throughout.

The fan chamber holds the reheater, the fan, the fan motor and drive. In the case of the 3-4 unit, the motor is housed within the fan casing while on the other sizes the motor is supported on an adjustable base mounted on the exterior of the casing. The fan in the 3-4 unit is of the double inlet type with backwardly tilted blades offering non-overloading characteristics at any given speed. The fans on the 2-2, 2-3, and 2-4 units are of the forward curve multi-blade type with operating characteristics requiring rather more careful selection of speeds and motors in accordance with the anticipated or calculated external resistance of distribution ducts, louvres, etc. The curves above provide an easy method for the suitable selection of motors and speeds for all units to meet given external resistance and volume requirements.

Dimension drawings of the full range of units appear on page 24.

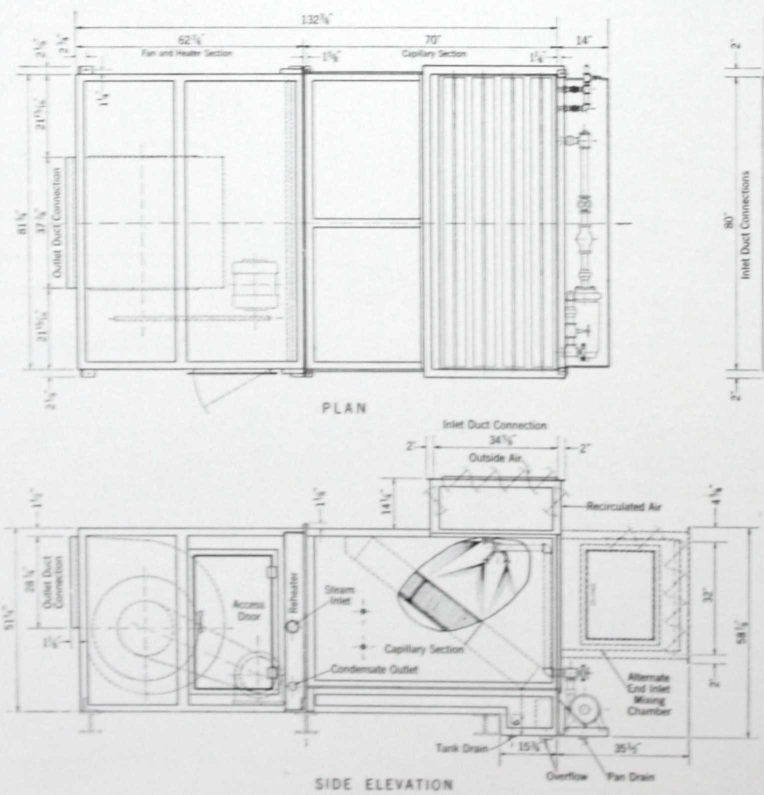
DIMENSIONED DRAWINGS OF CAPILLARY UNIT AIR CONDITIONERS

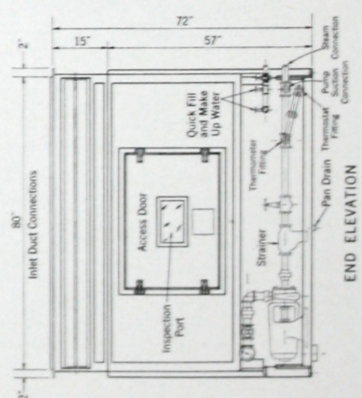




Unit Size	"A"	"B"	"C"	"D"	"E"	"F"
22	45¾"	44"	20⅛"	12 13/16"	19"	48¼"
23	61¾"	60"	45⅝"	8 1/16"	15¾"	64¼"
24	81¾"	80"	54⅝"	13 9/16"	19"	84¼"

Size 22, 23, and 24 Capillary Unit Air Conditioners.





Size 34 Capillary Unit Air Conditioner.

CAPILLARY

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